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L71

Storage of cured fisheries products in Malaysia

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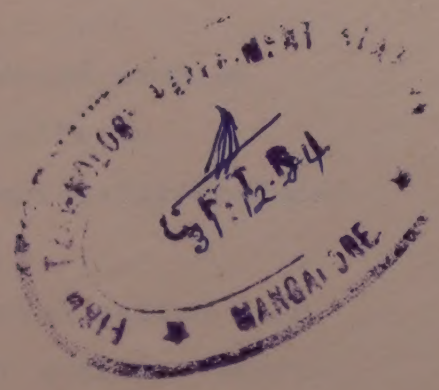
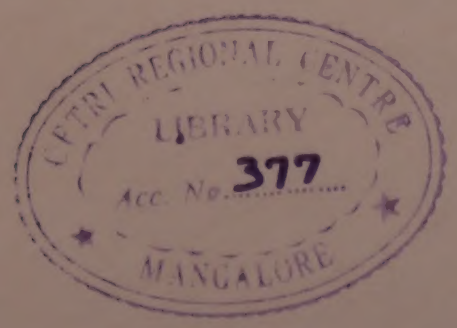
C. A. Curran





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1. SUMMARY

Salting and sun drying are the most important fish processing methods in Malaysia. Cured fish is very popular and is used by all sectors of the Malaysian population.

A review of the causes of the extensive post-harvest losses of cured fisheries products which occur in the tropics has shown that mould growth is one of the major problems. Recently, a simple method for calculating the water activity (a_w) of dried salted fish from their moisture and salt contents has been reported in the literature. This a_w value can then be used to predict the mould-free shelf life of the products. This has been further simplified to a Table which forms the basis of a simple guide for calculating the optimum salt and moisture contents necessary to obtain a desirable shelf life and maximum yield for cured products.

The objective of this study was to test this guide using Malaysian cured products which include invertebrate species and dried boiled products in addition to dried salted fish. The results indicated that the Table could be used successfully as a guide for dried salted fish and cephalopods. However, this particular Table cannot be used for dried boiled fish or shrimp; a separate table would have to be constructed to suit this type of product. The Table cannot be used to predict the shelf life of products which have been redried at some time during storage. Although redrying extended the storage life of the products, they spoiled much earlier than expected since any microbial attack or spoilage which occur between drying and redrying, or during redrying itself, are not reversible. The Table had to be expanded to include higher moisture contents which are a desired characteristic in some Malaysian dried salted fish. The method for using the a_w value to predict the mould-free shelf life was reliable for dried salted fish and cephalopods and possibly high quality dried boiled products; it cannot be used with redried fish. The sorption isotherms for unsalted freeze dried cod can be used to determine the a_w of dried boiled fish, such as anchovy, but not for crustaceans or cephalopods. A simple cheap a_w meter which was tested could be used reliably under controlled temperature conditions but could not be recommended for use in the field.

2. INTRODUCTION

2.1 Cured fisheries products in Malaysia

Although the world fish catch is increasingly being preserved by freezing, this is due largely to the growing popularity of frozen products in developed countries. However, in tropical countries, where chilling and freezing facilities are often lacking, traditional curing methods are still the main means of preserving fish which cannot be sold fresh (FAO, 1981).

Salting and sun drying are the most important fish processing methods in Malaysia (Zain and Yusof, 1983). As can be seen from Table 2.1, most of the marine catch is sold as fresh fish (60%); however, salted, dried and smoked products account for the second largest portion (12%) which is used for human consumption. In 1980, the per capita consumption of dried fish in Malaysia was 1.5 kg (Maynard, 1983).

Table 2.1 Disposition of marine fish landings in Malaysia, 1980

Product	Weight (T)	%
Fresh fish	377,169	60.4
Salted/dried/smoked	77,240	12.4
Steamed/boiled	7,993	1.3
Fermented	8,922	1.4
Fish meal	131,928	21.2
Other	20,646	3.3
Total	623,898	100.0

Source: Zain and Yusof (1983).

Dried fish is used by all sections of the Malaysian population. Markets in urban and provincial areas display a broad range of products and the consumers are very discriminating about quality (Maynard, 1983). The most important product is boiled dried anchovy (ikan bilis) which accounted for about 45% by weight of all dried products in 1980 (see Table 2.2). Other important species in terms of volume are dried cooked shrimp, dried salted red snapper and Indian mackerel.

Table 2.2 Dried fish production in Peninsular Malaysia, 1980

Product	Dried weight (T)	%
Salted/dried/smoked fish	8,000	37.6
Anchovy	9,500	44.6
Shrimp	1,300	6.1
Fish/shrimp crackers	700	3.3
Squid and cuttlefish	200	0.9
Cockles and shellfish	1,600	7.5
Total	21,300	100.0

Source: Adapted from Maynard (1983).

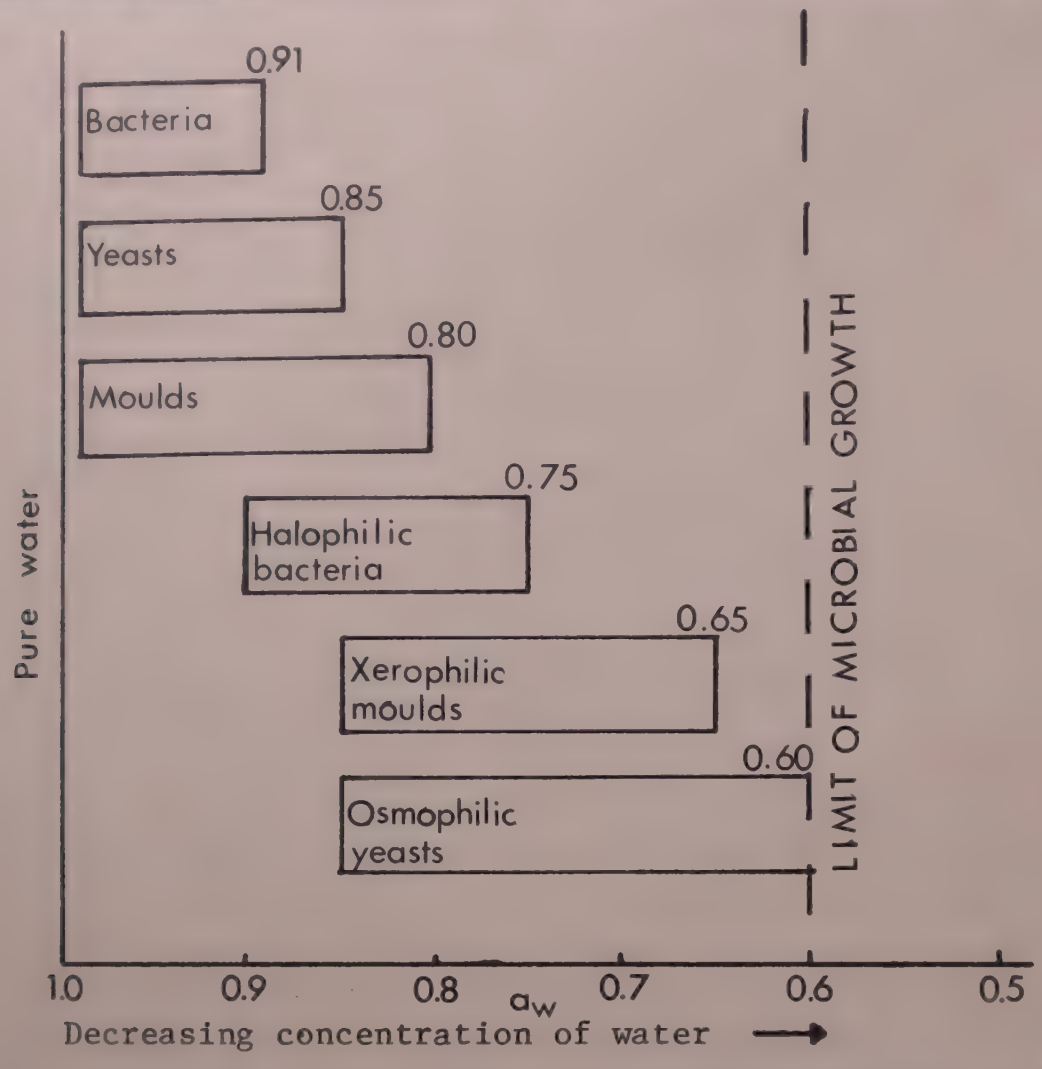
2.2 Water activity and storage life of cured fish

A recent review (FAO, 1981) highlighted the causes of post-harvest losses in cured fisheries products in the tropics; one of the major problems is mould growth. It is the water activity (a_w) of a food which mainly influences its susceptibility to microbial attack. The a_w value is a measure of the free or available water in the food which is able to react chemically or to support the growth of micro-organisms during spoilage (Waterman, 1976). Pure water has been assigned an a_w value of 1.0. The a_w of food is expressed as a fraction relative to pure water; fresh fish has an a_w above 0.95.

Traditional processes such as salting and drying preserve fish principally by reducing the a_w which, in turn, reduces the range and number of micro-organisms that can attack and spoil the product. The relationship between a_w and the growth of various types of micro-organisms is shown in Fig. 2.1. At a_w levels below 0.85, normal spoilage bacteria and yeasts are inhibited; the red, salt-tolerant halophilic bacteria, xerophilic moulds and osmophilic yeasts predominate and it is these organisms which may attack cured fisheries products.

Figure 2.1

Growth range of micro-organisms with respect to water activity



Source: FAO (1981).

In an attempt to find a simple method for determining the a_w of cured fish products, earlier work at the Tropical Development and Research Institute (TDRI) concentrated on investigating the relationship between their a_w and their water and salt contents. It was found that the a_w of dried salted fish could be calculated from the following equation:

$$a_w = a_{wn} \cdot a_{wo} \qquad (1)$$

where a_{wn} is the water activity of the salt-water component of the fish and a_{wo} is the water activity of the fish muscle (Doe *et al.*, 1982). The a_w of the salt in the fish is taken to be the same as that of a pure sodium chloride solution at a molality, m, which is calculated from the measured water and salt contents using the equation:

$$m = 17.09 \, (M_s/M_b) \cdot (M_b/M_w) \qquad (2)$$

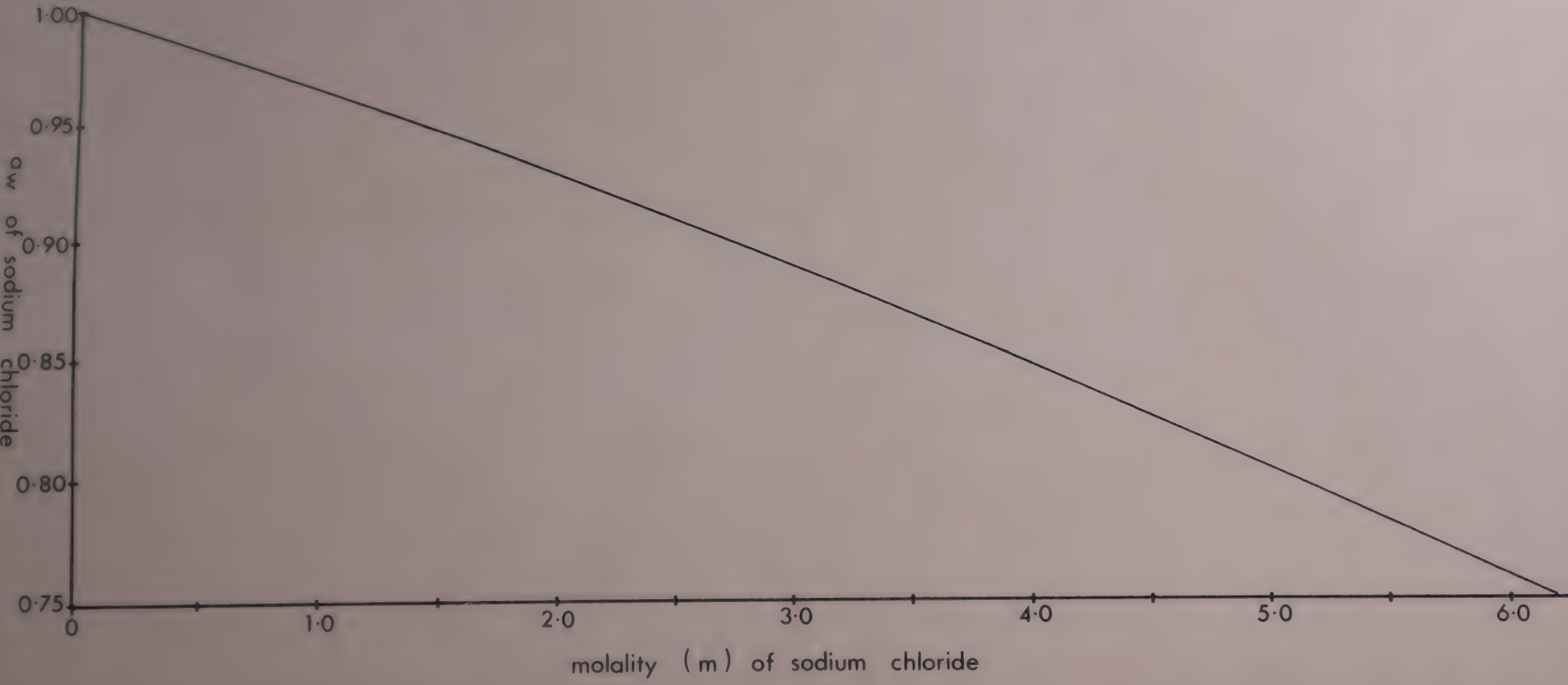
where M_s is the mass of salt, M_w is the mass of water and M_b is the salt-free, fat-free dry mass. The relationship between a_w and m can be obtained from the literature (Robinson and Stokes, 1959) and is shown in Fig. 2.2. Values for a_{wo} at different water contents can be determined from the sorption isotherm for unsalted cod (Doe *et al.*, 1982) given in Fig.2.3. To simplify this further, Doe *et al.* (1983) presented a table giving the a_w values corresponding to different water (M_w/M_b) and salt (M_s/M_b) contents (see Table 2.3).

In humid, tropical climates, cured fish flesh will absorb moisture from the air during storage until an equilibrium is reached. This increases the a_w and the product becomes more susceptible to spoilage by moulds and bacteria. The xerophilic moulds which cause dun and the brown discoloration associated with localized decay are the most troublesome (Liston, 1980) but halophilic bacteria may be important in salted products. Fig. 2.4 indicates the time required for germination and growth to visible colonies of the dun mould, *Wallemia sebi*, at different a_w values. Poulter *et al.*(1982) used this figure to predict the mould-free shelf life of dried salted fish under tropical conditions. In theory, cured fish with an a_w above the curve at a particular storage time will be liable to suffer from mould attack while fish with an a_w below the curve will not. During storage trials on seven cured fish species from Sri Lanka, Poulter *et al.*(1982) found that their predictions were in good agreement with the actual shelf life of the products. This work lead to the construction of Table 2.4 (Poulter, 1980) which is a guide to the relationship between composition and storage life of dried fish.

This Table forms the basis of a simple guide for extension workers and dried fish producers to enable them to calculate the optimum water and salt contents necessary to obtain a desirable shelf life and maximum yield for cured products. The purpose of this study was to test this guide using Malaysian cured products which include both fish and invertebrate aquatic species, such as crustaceans and cephalopods, and boiling as well as salting and drying during processing.

Figure 2.2

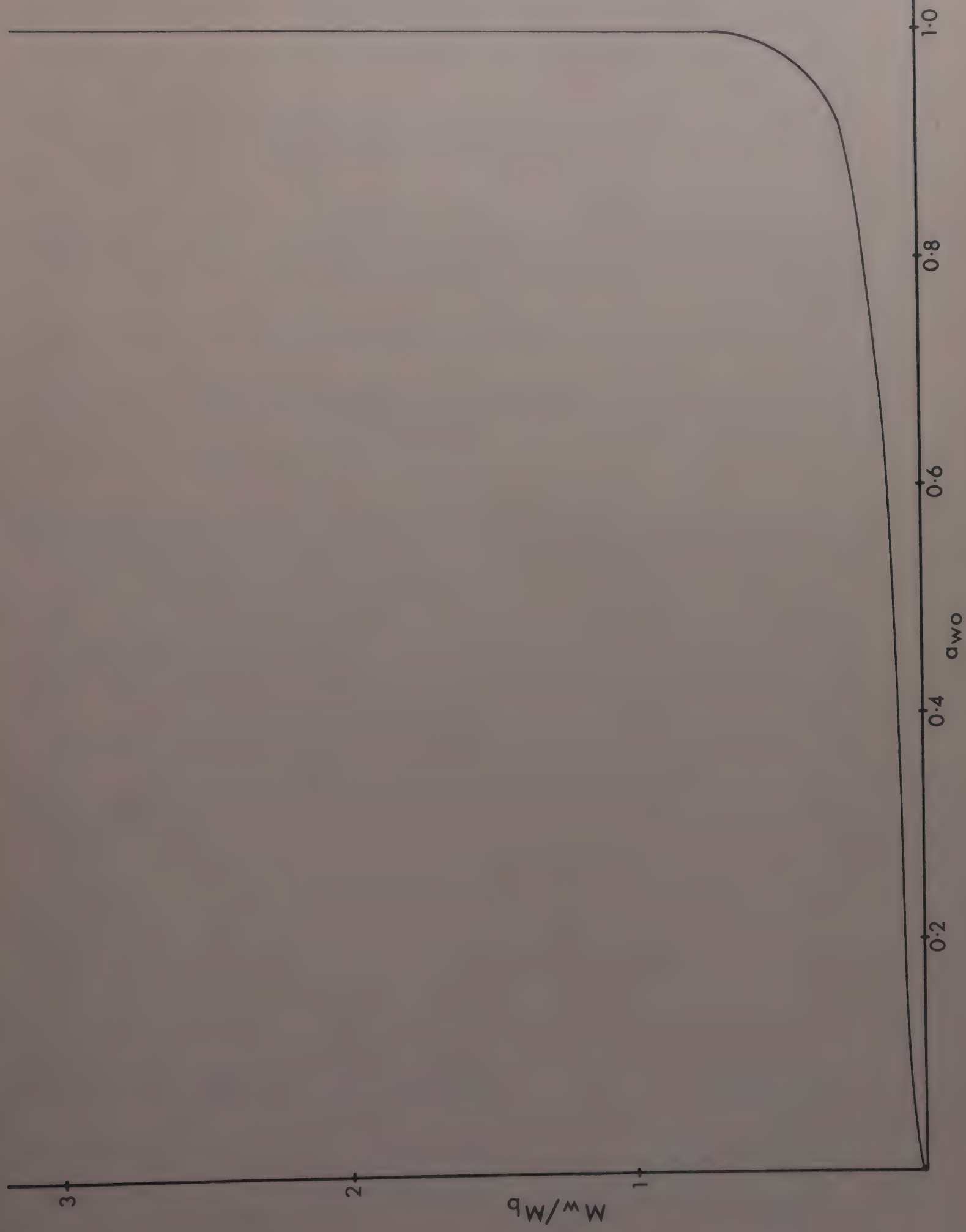
Relationship between water activity and molality of sodium chloride solutions at 25°C



Source of data: Robinson and Stokes (1959).

Figure 2.3

Water sorption isotherm for freeze dried unsalted cod at 25°C



Source of data: Doe *et al*. (1982).

Table 2.3 Water activity calculated from water and salt contents

Water content (M_w/M_b) | Salt content (M_s/M_b)

	0	.02	.04	.06	.08	.10	.12	.14	.16	.18	.20	.22	.24	.26	.28	.30	.35	.40	.45	.50	.55	.60	.65	.70	.75	.80	.85	.90	.95	1.0
.02	.04	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03
.04	.09	.07	.07	.07	.07	.07	.07	.07	.07	.07	.07	.07	.07	.07	.07	.07	.07	.07	.07	.07	.07	.07	.07	.07	.07	.07	.07	.07	.07	.07
.06	.17	.13	.12	.12	.12	.12	.12	.12	.12	.12	.12	.12	.12	.12	.12	.12	.12	.12	.12	.12	.12	.12	.12	.12	.12	.12	.12	.12	.12	.12
.08	.26	.21	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19
.10	.47	.41	.35	.35	.35	.35	.35	.35	.35	.35	.35	.35	.35	.35	.35	.35	.35	.35	.35	.35	.35	.35	.35	.35	.35	.35	.35	.35	.35	.35
.12	.59	.53	.46	.44	.44	.44	.44	.44	.44	.44	.44	.44	.44	.44	.44	.44	.44	.44	.44	.44	.44	.44	.44	.44	.44	.44	.44	.44	.44	.44
.14	.69	.63	.56	.51	.51	.51	.51	.51	.51	.51	.51	.51	.51	.51	.51	.51	.51	.51	.51	.51	.51	.51	.51	.51	.51	.51	.51	.51	.51	.51
.16	.75	.69	.63	.56	.56	.56	.56	.56	.56	.56	.56	.56	.56	.56	.56	.56	.56	.56	.56	.56	.56	.56	.56	.56	.56	.56	.56	.56	.56	.56
.18	.80	.74	.68	.61	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60	.60
.20	.83	.79	.73	.67	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62
.22	.86	.82	.77	.71	.65	.65	.65	.65	.65	.65	.65	.65	.65	.65	.65	.65	.65	.65	.65	.65	.65	.65	.65	.65	.65	.65	.65	.65	.65	.65
.24	.89	.85	.80	.75	.69	.67	.67	.67	.67	.67	.67	.67	.67	.67	.67	.67	.67	.67	.67	.67	.67	.67	.67	.67	.67	.67	.67	.67	.67	.67
.26	.91	.87	.82	.78	.72	.68	.68	.68	.68	.68	.68	.68	.68	.68	.68	.68	.68	.68	.68	.68	.68	.68	.68	.68	.68	.68	.68	.68	.68	.68
.28	.93	.89	.85	.80	.75	.70	.69	.69	.69	.69	.69	.69	.69	.69	.69	.69	.69	.69	.69	.69	.69	.69	.69	.69	.69	.69	.69	.69	.69	.69
.32	.95	.92	.88	.84	.80	.75	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71
.36	.96	.93	.90	.87	.83	.79	.74	.72	.72	.72	.72	.72	.72	.72	.72	.72	.72	.72	.72	.72	.72	.72	.72	.72	.72	.72	.72	.72	.72	.72
.40	.97	.95	.92	.89	.85	.82	.78	.74	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73
.44	.98	.96	.93	.90	.87	.84	.81	.77	.74	.74	.74	.74	.74	.74	.74	.74	.74	.74	.74	.74	.74	.74	.74	.74	.74	.74	.74	.74	.74	.74
.48	.99	.96	.94	.91	.89	.86	.83	.80	.76	.74	.74	.74	.74	.74	.74	.74	.74	.74	.74	.74	.74	.74	.74	.74	.74	.74	.74	.74	.74	.74
.52	.99	.97	.95	.93	.90	.87	.85	.82	.79	.75	.74	.74	.74	.74	.74	.74	.74	.74	.74	.74	.74	.74	.74	.74	.74	.74	.74	.74	.74	.74
.56	1.0	.98	.96	.93	.91	.89	.86	.84	.81	.78	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75
.60	1.0	.98	.96	.94	.92	.90	.87	.85	.82	.80	.77	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75
.64	1.0	.98	.96	.94	.93	.90	.88	.86	.84	.81	.79	.76	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75
.68	1.0	.98	.97	.95	.93	.91	.89	.87	.85	.83	.80	.78	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75
.72	1.0	.98	.97	.95	.93	.92	.90	.88	.86	.84	.82	.78	.77	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75
.76	1.0	.99	.97	.96	.94	.92	.90	.89	.87	.85	.83	.81	.79	.76	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75
.80	1.0	.99	.97	.96	.94	.93	.91	.89	.88	.86	.84	.82	.80	.78	.76	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75
.84	1.0	.99	.97	.96	.95	.93	.92	.90	.88	.87	.85	.83	.81	.79	.77	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75
.88	1.0	.99	.98	.96	.95	.93	.92	.90	.89	.87	.86	.84	.82	.80	.79	.76	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75
.92	1.0	.99	.98	.96	.95	.94	.92	.91	.89	.88	.86	.85	.83	.81	.80	.78	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75
.96	1.0	.99	.98	.97	.95	.94	.93	.91	.90	.88	.87	.85	.84	.82	.81	.79	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75
1.0	1.0	.99	.98	.97	.96	.94	.93	.92	.90	.89	.88	.86	.85	.83	.82	.80	.76	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75
1.5	1.0	.99	.98	.98	.97	.96	.95	.95	.94	.93	.92	.91	.90	.89	.89	.88	.85	.83	.80	.77	.75	.75	.75	.75	.75	.75	.75	.75	.75	.75
2.0	1.0	1.0	.99	.98	.98	.97	.97	.96	.96	.95	.94	.94	.93	.92	.92	.91	.89	.88	.86	.84	.82	.80	.78	.76	.75	.75	.75	.75	.75	.75
2.5	1.0	1.0	.99	.99	.98	.98	.97	.97	.96	.96	.96	.95	.95	.94	.94	.93	.92	.90	.89	.88	.87	.85	.83	.82	.80	.78	.77	.75	.75	.75
3.0	1.0	1.0	.99	.99	.99	.98	.98	.97	.97	.97	.96	.96	.96	.95	.95	.94	.93	.92	.91	.90	.89	.88	.86	.85	.84	.83	.81	.80	.79	.77
3.5	1.0	1.0	.99	.99	.99	.98	.98	.98	.98	.97	.97	.96	.96	.96	.96	.95	.94	.93	.92	.92	.91	.90	.89	.88	.87	.86	.84	.83	.82	.81
4.0	1.0	1.0	1.0	.99	.99	.99	.98	.98	.98	.98	.97	.97	.97	.96	.96	.96	.95	.94	.93	.93	.92	.91	.90	.89	.88	.88	.87	.86	.85	.84

Source: Doe *et al.* (1983).

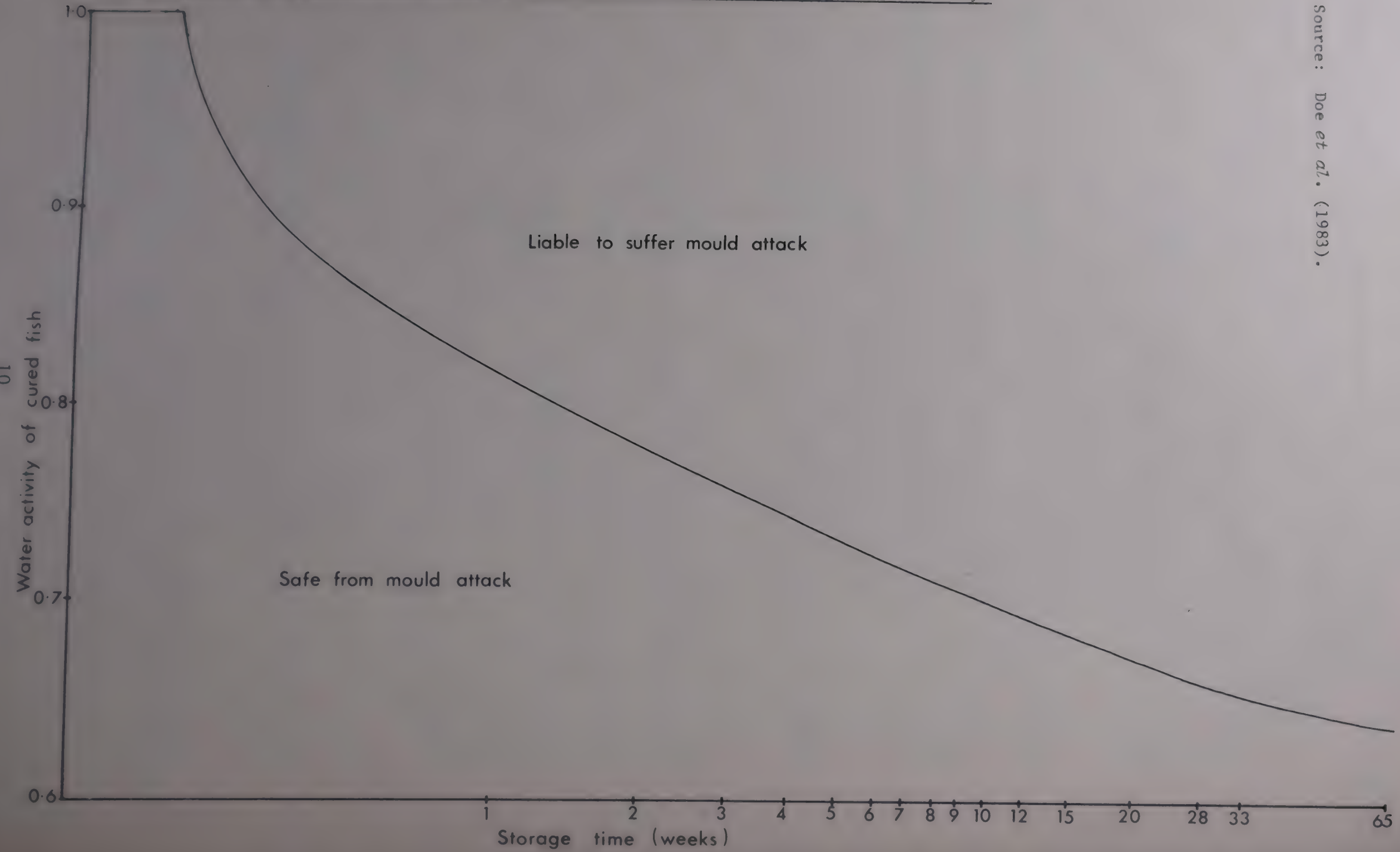
Table 2.4 Rough guide to the good quality storage life of dried fish with different water and salt contents

Water content (% wet weight)	Salt content (% wet weight)	Minimum "good quality" storage life
40	5	½ week
40	10	1 week
40	15	3 weeks
40	20	1½ months
35	5	½ week
35	10	2 weeks
35	15	2 months
35	20	1½ months
30	5	½ week
30	10	1½ months
30	15	2 months
30	20	2 months
25	5	1 week
25	10	2½ months
25	15	2 months
25	20	2 months
20	5	3 weeks
20	10	4 months
20	15	4 months
20	20	3½ months
15	5	more than one year
15	10	more than one year
15	15	more than one year
15	20	more than one year

Source: Poulter (1980).

Figure 2.4

Prediction of mould-free storage life of cured fish products from their water activity



Source: Doe *et al.* (1983).

3. EXPERIMENTAL WORK

The work was concentrated in five main areas:

(1) Storage of commercially produced samples;

(2) Determination of sorption isotherms;

(3) Redrying and storage of commercially produced samples;

(4) Processing and storage of dried salted fish;

(5) Testing an inexpensive water activity meter.

3.1 Storage of commercially produced samples

3.1.1 Materials: Seventeen dried fisheries products were purchased from Penang markets at the beginning of November 1982. A list of these products with their common English and Malay names, their scientific name and their market price is given in Table 3.1.

3.1.2 Storage: All of the samples were kept in a well-ventilated storeroom at the Institut Perikanan Malaysia (IPM), Penang. To imitate the practices in the local markets, the squid and octopus were kept in open cardboard boxes; the snapper and queenfish were placed in piles on hessian stacking; the packed threadfin were left in their sealed polyethylene bags; and the remaining samples were kept in rattan baskets. The temperature and relative humidity in the storeroom were measured continuously using a recording thermohygrograph (C.F. Casella & Co. Ltd., London).

3.1.3 Quality assessment: The initial quality of the samples was assessed visually, noting the extent of the occurrence of moulds, pinking caused by halophilic bacteria, beetles, rancidity and putrefaction. A grade was given according to local preferences. In addition, moisture, salt, fat, protein, ash and acid insoluble ash contents were determined by the standard AOAC (1965) methods. At regular intervals during storage, the samples were visually assessed for quality and the moisture and

salt contents determined. Their a_w values were calculated using the method described in Section 2.2 (Doe *et al.*, 1982 and 1983). Storage was continued until the products were given an unacceptable grading.

Table 3.1 Commercially produced Malaysian cured fisheries products used during storage trials

Sample no.	Common English name	Common Malay name	Scientific name	Market price (M$/kg)*
1	Octopus	Sotong (Keretah)	Unknown species	6.60
2	Squid	Sotong	Unknown species	22.00
3	Shrimp, high grade	Udang	Unknown species	9.00
4	Shrimp, low grade	Udang	Unknown species	7.00
5	Anchovy, high grade	Bilis	Stolephorus commersonii	10.00
6	Anchovy, low grade	Bilis	Stolephorus commersonii	9.00
7	Queenfish	Talang	Scomberoides sp.	5.00
8	Red snapper	Merah	Lutianus argentimaculatus	5.20
9	Threadfin, boneless	Kurau	Polynemus sp.	13.00
10	Threadfin, with bones	Kurau	Polynemus sp.	11.50
11	Threadfin, 115g packs	Kurau	Polynemus sp.	12.00
12	Sardine	Tamban	Sardinella sp.	3.00
13	Mackerel	Kembong	Rastrelliger sp.	2.00
14	Jewfish, whole	Gelama	Johnius (Pseudosciaena) soldado	2.30
15	Jewfish, split	Gelama	Johnius (Pseudosciaena) soldado	3.00
16	Pomfret	Bawal	Pampus argenteus	3.80
17	Catfish	Duri	Tachysurus caelatus	3.00

* £1 = M$3.78 (November 1982).

3.2 Determination of sorption isotherms

3.2.1 Species: Sorption isotherms were determined for cured octopus, squid, shrimp and anchovy.

3.2.2 Water activity measurements: The samples were cut into small pieces (5 mm^3) and freeze dried. They were then equilibrated over saturated solutions of various salts of a_w in the range 0.07 - 0.90 at a temperature of 25°C in partially evacuated desiccators as described by Doe *et al.* (1982). When the samples reached a constant weight, they were analysed in duplicate for moisture and sodium chloride contents by the AOAC (1965) methods. The original freeze dried samples were also analysed for moisture, salt, fat, protein and ash (AOAC, 1965).

3.3 Redrying and storage of commercially produced samples

3.3.1 Materials: Five samples were purchased from the local markets: queenfish, red snapper, threadfin, jewfish and pomfret. Initial moisture and salt contents were measured (AOAC, 1965) and used to estimate the amount of redrying required to extend the shelf life by several weeks using the results of the earlier TDRI work on water activity (Fig. 2.4 and Table 2.4) as a guide.

3.3.2 Redrying: The samples were divided into two equal portions: one half was redried before storage and the other half was placed immediately into the storeroom and used for comparison. Initially, the fish were placed on racks to dry in the sun. They were turned and weighed regularly. However, the weather was very cloudy, wet and humid so that drying progressed very slowly and after three days very little weight loss had been achieved. As a result, it was necessary to dry the fish mechanically in a Torry mini-kiln (Afos Ltd., Hull) at 40°C. The redried samples were analysed for moisture and salt contents (AOAC, 1965).

3.3.3 Storage: The fish were stored in the same manner as the commercial samples (Section 3.1.2). The queenfish and snapper were placed in piles on hessian sacking and the pomfret, jewfish and threadfin in rattan baskets in a well-ventilated room.

3.3.4 Quality assessment: The redried and non-redried samples were visually assessed in the same way as the commercial samples (see Section 3.1.3) both initially and at regular intervals during storage until they were judged to be unacceptable.

3.4 Processing and storage of dried salted fish

3.4.1 Materials: Fresh threadfin bream, Nemipterus sp., and hairtail scad, Megalaspis cordyla, locally known as kerisi and cincaru respectively, were purchased from local markets in Penang. The samples were held on ice in a chill room until processed.

3.4.2 Processing: The bream were split along the back, carefully gutted and then washed. The scad were processed whole but two score cuts were made on both sides of the fish to facilitate salt penetration. The fish were soaked in brine and then dried in the Torry mini-kiln, initially at 30°C and then at 40°C, for varying lengths of time to give a range of 8 moisture (20-40%) and salt (5-15%) contents.

3.4.3 Storage: The final dried salted products were kept in rattan baskets in a well-ventilated storeroom.

3.4.4 Quality assessment: The quality of the fish was assessed visually as described in Section 3.1.3 after processing was completed and during storage. The moisture and salt contents of the initial dried salted products were determined and proximate analysis was carried out on the wet fish.

3.5 Testing an inexpensive water activity meter

3.5.1 The meter: The a_w-Value Analyzer model no. 5803 (G. Lufft GmbH & Co., Stuttgart) costs approximately DM 400 (£100). It consists of a "styropor" case holding two sample containers each with a removable sensor head which indicates a_w and temperature on dials.

3.5.2 Operation: One container is used to hold the sample under test while filter papers soaked in a standard solution of barium chloride (a_w = 0.9 at 20°C) are placed in the second which is used for calibration. The sensor head must first be calibrated by securing it on to the container holding the filter papers and leaving it for 3 hours. The head is calibrated by applying the supplied wrench to the adjustment screw until the correct a_w (corrected for temperature) is indicated on the dial. The head is removed and, after two minutes, is secured to

the container which holds the sample. The a_w of the sample can be read from the dial after 3 hours and is adjusted for temperature (a_w + 0.002 for each 1°C above 20°C).

3.5.3 Materials: The a_w values of twenty different cured fisheries products used during the other experimental work (Sections 3.1 - 3.4) were determined using the meter. These values were compared with those obtained by calculation using the method described by Doe *et al.* (1982 and 1983) as outlined earlier (see Section 2.2).

4. RESULTS

4.1 Storage of commercially produced samples

4.1.1 Storage conditions: A summary of the continuous measurement of temperature and relative humidity (% RH) in the storeroom during the trials is given in Table 4.1.

Table 4.1 Summary of the storage conditions in the storeroom

Month	Temperature (°C)		% RH	
	Mean	Range	Mean	Range
November	28.5	25.0 - 31.5	77	58 - 88
December	28.5	25.0 - 32.0	74	53 - 88
January	28.5	24.5 - 32.5	69	50 - 88
February	30.0	25.5 - 34.5	67	44 - 86
March	31.0	27.5 - 35.0	67	45 - 85

4.1.2 Proximate composition: The fat, protein, ash, acid insoluble ash and salt contents of all seventeen samples on a dry weight basis are given in Table 4.2.

4.1.3 Octopus: The exact processing method used for these samples is unknown. However, in one of the production areas, Port Weld in Kedah, they are slit open and gutted. After washing, they are left in coarse salt for 3 hours. They are then sun dried on racks (which are either laid horizontally or slanted and rotated to follow the sun during drying) for several days until they become translucent.

When purchased, the octopus samples were tied together in bunches weighing 200-300 g. The body (without tentacles) measured 8 cm in length and was translucent yellow/brown in colour with a few dark areas (e.g. purple eye spots). The initial quality was very good and the samples had a strong salty, musty, astringent odour which is characteristic of the product. One mite was seen on the samples.

The change in quality during storage is shown in Table 4.3. After 10 days' storage, there was no change in odour but a few small yellow

Table 4.2 Proximate composition (% dry weight basis) of the commercially produced samples

Sample no.	Species	% Fat	% Protein	% Ash	% Acid insoluble ash	% Salt
1	Octopus	0.9	80.7	15.2	0.9	10.4
2	Squid	4.3	87.8	8.7	1.0	3.8
3	Shrimp, high quality	2.8	74.1	20.3	1.0	15.1
4	Shrimp, low quality	1.5	71.4	27.4	1.3	19.8
5	Anchovy, high quality	4.3	78.9	21.6	1.0	13.1
6	Anchovy, low quality	2.8	74.0	27.8	2.5	19.6
7	Queenfish	1.9	65.0	34.2	0.4	30.5
8	Red snapper	0.6	72.3	35.3	1.9	31.2
9	Threadfin boneless	1.2	70.4	23.7	1.0	17.1
10	Threadfin, with bones	0.8	70.5	28.7	0.6	24.2
11	Threadfin, 115g packs	1.5	74.7	27.4	2.2	25.0
12	Sardine	4.7	80.7	19.2	1.3	9.7
13	Mackerel	12.5	54.3	37.6	3.3	31.3
14	Jewfish, whole	6.1	52.2	38.3	1.2	33.9
15	Jewfish, split	1.1	61.5	30.0	2.0	30.0
16	Pomfret	2.5	51.6	54.7	1.8	45.1
17	Catfish	8.2	59.4	30.3	0.6	24.2

mould colonies had appeared on a few samples. At 16 days' storage, the octopuses were heavily covered with green and white moulds while the odour had become slightly sour and ammoniacal. A few mites were seen in the container. They were graded as unacceptable due to the mould growth.

4.1.4 Squid: Although the origin and exact processing of these samples are not known, in Pulau Pangkor, squid are slit and their quill (backbone), ink sac and guts are removed. After washing, they are sun dried on racks. Many different grades are produced.

The samples for this study had a body length of 15 cm and a well-dried, leathery texture. The body was mainly purple in colour, with a few transparent yellow areas, and had a white powdery substance covering it. The initial quality was very high and the squid had a fresh, fruity, salty, leathery odour.

The quality changes during storage are given in Table 4.3. There was no deterioration in quality after 10 days. However, at 16 days' storage, the squid were covered extensively by green and white moulds which could not be easily removed and this caused them to be graded as unacceptable.

4.1.5 Shrimp: The shrimp were imported from Thailand into Malaysia. Traditionally, these are cooked in brine before being sun dried on mats on the ground for about one day. There are many different grades depending upon colour, species, size etc.

Two grades of shrimp were purchased for this study. The higher grade had a body length of 15 mm (excluding head and tail) and were headed but the shell, legs and tail were still present. They had a soft, fairly dry texture and were pink/orange in colour. The odour was fresh. Their colour and small size command a higher price for this grade. The lower grade shrimp were much larger at 30 mm body length and also only had the head removed. They had a soft, damp texture and appeared to be a wetter product than the higher grade. These shrimp were yellow/brown in colour and they smelt slightly of urea and were musty. They were not as fresh in quality as the other samples.

Table 4.3 Quality changes during storage of dried octopus and squid

Species	Storage time (days)	Moisture			Salt			a_w++	Moulds	Pinking	Beetles	Rancidity	Putre-faction	Grade
		%*	M_w/M_b	a_{wo}**	%*	m	a_{wn}+							
Octopus	0	33.6	0.57	0.92	6.9	3.51	0.87	0.80	None	None	None	None apparent	None	Good
	10	31.1	0.51	0.90	7.0	3.85	0.86	0.77	Very slight	None	None	None apparent	None	Good
	16	33.3	0.57	0.92	8.3	4.27	0.84	0.77	Extensive	None	None	None apparent	Slight	Un-acceptable
Squid	0	26.3	0.39	0.79	2.8	1.82	0.93	0.73	None	None	None	None apparent	None	Good
	10	26.0	0.38	0.79	2.5	1.64	0.94	0.74	None	None	None	None apparent	None	Good
	16	27.5	0.41	0.81	2.0	1.24	0.95	0.77	Extensive	None	None	None apparent	None	Un-acceptable

* Wet weight basis.

** Calculated from sorption isotherms for octopus and squid (Figs. 4.3 and 4.4 respectively).

\+ Calculated from Fig. 2.2.

++ Calculated using Equation (1).

The changes in quality for both grades during storage are indicated in Table 4.4. Within 10 days' storage, the high grade shrimp had become wetter and their odour was musty. After one month, their colour became browner and less pink and they smelt of urea. The low grade shrimp also became wetter during storage and, within 10 days, they had a urea odour. After one month, this odour was very strong and the colour had changed from orange to pink due to spoilage by halophilic bacteria. This pink colour was deceptive because it gave the appearance of a higher quality product. By the next sampling day, all of the shrimp, and several other samples, had been stolen from the store, probably by rats. It was, therefore, not possible to continue these trials until an unacceptable grading had been achieved.

4.1.6 Anchovy: Various grades and ranges of quality of dried anchovy are available in Malsysia, in general, the smaller the size, the higher the price of the fish. Processing on the East and West Coasts differs. On the West Coast, the area from which the samples for this study would have been obtained, the fish are caught in large quantities by purse seiners. They are a small species (2.5 - 5.0 cm long) which spoil rapidly but they are very delicate fish and are easily physically damaged by the crushed block ice which is generally used for chilling. Consequently, they are usually processed on board. They are first boiled in bamboo baskets in 10% brine for one minute with agitation during the cooking. The baskets are removed from the brine and allowed to drain and cool. On landing, the fish are spread to dry in the sun usually for one day but for longer under poor drying conditions.

Two grades of this product were used for the study. The higher grade anchovy were 5 cm long and whole fish. The body was yellow/brown in colour with a silver strip along the body and head; the texture was fairly dry and leathery and the odour very fresh, fruity and sweet. The colour, drier product and intact fish are the characteristics which command a higher price. The lower grade fish were the same length but most of the heads were missing. The body was grey and the strip often bruised. The fish had been physically damaged during processing and suffered fragmentation. The product was wetter but had the same leathery texture while the odour was musty and oily.

Table 4.4 Quality changes during storage of dried cooked shrimp

Sample	Storage time (days)	Moisture			Salt			a_w++	Moulds	Pinking	Beetles	Rancidity	Putre-faction	Grade
		%*	M_w/M_b	a_{wo}**	%*	m	a_{wn}+							
Shrimp, high grade	0	32.4	0.58	0.96	10.2	5.38	0.79	0.76	None	None	None	None apparent	None	Good
	10	34.7	0.63	0.97	8.8	4.33	0.84	0.81	None	None	None	None apparent	None	Good
	16	34.7	0.65	0.97	10.2	5.02	0.80	0.78	None	None	None	None apparent	Slight	Good
	30	36.3	0.72	0.98	11.5	5.41	0.79	0.77	Very Slight	None	None	None apparent	Slight	Average
	61 (missing)													
Shrimp, low grade	0	32.9	0.62	0.97	13.3	6.91	0.75	0.73	None	None	None	None apparent	Slight	Good/ average
	10	37.7	0.76	0.98	11.9	5.40	0.79	0.77	None	None	None	None apparent	Slight	Average
	16	39.0	0.80	0.99	11.1	4.86	0.81	0.80	None	None	None	None apparent	Moderate	Poor/ average
	30	38.9	0.79	0.99	10.9	4.79	0.82	0.81	None	Exten-sive	None	None apparent	Moderate	Poor/ average
	61 (missing)													

* Wet weight basis.

** Calculated from sorption isotherm for shrimp (Fig. 4.5).

\+ Calculated from Fig. 2.2.

++ Calculated using Equation (1).

The storage changes are given in Table 4.5. There was little change in odour of either grade until 16 days' storage; at that time, the high grade fish had a more neutral odour which was slightly oily and the low grade anchovies were beginning to smell slightly rancid. There was some mould growth on both products. After one month, the high grade product had begun to become rancid, a few mites were present, and mould growth was fairly extensive; the fish were considered to be of poor quality. The samples had been stolen from the store before the next sampling day so that the trial was terminated prematurely. After the same storage time, the low grade product smelt strongly of ammonia, and had been heavily attacked by mould; this caused them to be graded as unacceptable. A few mites were also present on these fish.

4.1.7 Queenfish: The fresh fish are imported into Malaysia mainly from Thailand and Singapore although some are caught locally. At the processor's in Penang, they are scaled, split in a butterfly cut, gutted (the gills are left in place) and washed. Queenfish are then pickle salted for two days using 100 parts fish: 30 parts salt. Dry salt is first rubbed into the flesh; the fish are then packed in dry salt in wooden tubs and left for one day. On the second day, pickle is added to cover the fish. The fish are weighted down during salting. After being washed in fresh water, they are set to dry in the sun on rattan mats in the drying yard. This takes approximately two days but may require up to five days during adverse drying weather. During bad weather, the fish are taken into a cold room.

The fish were about 60 cm long. Although they had been split dorsally with a butterfly cut, the extra flap was not opened out during storage in the local markets. There was some gut material remaining. The flesh was yellow/brown and orange in places; it was fairly moist, glazed in some areas from the oil and had a springy texture when pressed. There were no insects present but the flesh had some black speckles on the surface indicating blowfly attack. The odour was fresh and oily. Table 4.6 details the changes in quality during storage. After 10 days' storage, the odour had become slightly rancid. There was heavy pinking on half of the fish and a few small white mould colonies on all of the samples. The odour became very strongly pungent, fruity and sweet by 16 days and the flesh was very moist showing signs of sweating. The mould growth (white and green colonies) had become

Table 4.5 Quality changes during storage of dried boiled anchovy

Species	Storage time (days)	Moisture		Salt		a_w**	Moulds	Pinking	Beetles	Rancidity	Putre-faction	Grade
		%*	M_w/M_b	%*	M_s/M_b							
Anchovy, high grade	0	29.5	0.51	9.2	0.16	0.79	None	None	None	None apparent	None	Good
	10	31.4	0.58	11.1	0.20	0.76	None	None	None	None apparent	None	Good
	16	33.0	0.61	9.9	0.18	0.80	Very slight	None	None	None apparent	None	Good
	30	32.4	0.59	9.6	0.17	0.81	Fairly extensive	None	None	Slight	Slight	Poor
	61 (missing)											
Anchovy, low grade	0	38.9	0.82	12.0	0.25	0.80	None	None	None	None apparent	None	Good/ average
	10	37.9	0.81	13.6	0.29	0.76	None	None	None	None apparent	None	Average
	16	39.5	0.84	11.6	0.25	0.76	Slight	None	None	Slight	Slight	Average
	30	39.2	0.82	11.5	0.24	0.81	Very extensive	None	None	Slight	Fairly extensive	Unaccept-able

* Wet weight basis.

** Calculated from Table 2.3.

fairly extensive by that time as had pinking which affected all of the fish. After one month's storage, the odour was sweet, oily and rancid and the flesh was darker. The queenfish were unacceptable by two months due to mould growth and their putrid odour. A few blowfly maggots were found on the fish from 10 days onwards and evidence of beetle infestation was found after 16 days.

4.1.8 Red snapper: Iced red snapper are imported into Malaysia from Indonesia via Thailand or Singapore. They are processed in Penang by the same method as the queenfish (see Section 4.1.7).

The fish studied during this work were 50 cm long. Like the queenfish, they had been split dorsally in a butterfly cut but the flap was opened out. Although they had been gutted, some material was still present and the gills were intact. The flesh was yellow but there were orange patches around the gills, bones and gut. The texture was springy when pressed and fairly well dried. The odour was very fresh. A blowfly maggot was seen on one of the fish and there were black speckles, evidence of blowfly attack, on the flesh of all of the fish.

Table 4.7 details the changes in quality during storage. A few white and brown mould colonies appeared on the fish after 10 days' storage and half of the samples had heavy pinking. The odour was still fairly fresh and the fish had been sweating. Even after 16 days very little mould growth had occurred but all of the fish suffered from heavy pinking. The odour was strong and fruity. At this time, signs of beetle infestation had appeared. After one month, the fish were considered to be unacceptable due to the heavy pinking; the odour was still strongly sweet but also musty and there was quite a heavy maggot infestation.

4.1.9 Threadfin: This fish is imported into Malaysia already salted and dried from Burma. The processing method is not known. However, the processor in Penang will possibly redry the fish on mats in the sun before cutting the fish into various sized portions and will possibly pack the smaller pieces into polyethylene bags. Various grades are available depending upon the 'cut'.

Table 4.6 Quality changes during storage of dried salted queenfish

Storage time (days)	Moisture		Salt		a_w**	Moulds	Pinking	Beetles	Rancidity	Putre-faction	Grade
	%*	M_w/M_b	%*	M_s/M_b							
0	53.5	1.70	14.2	0.45	0.82	None	None	None	None apparent	None	Good
10	52.1	1.56	13.6	0.41	0.84	Slight	Fairly extensive	None	Slight	Slight	Good
16	54.7	1.80	14.1	0.47	0.82	Fairly extensive	Extensive	A few *Dermestes* and *Necrobia* adults	Moderate	Moderate	Average
30	51.0	1.49	13.8	0.40	0.83	Fairly extensive	Extensive	A few *Dermestes* and *Necrobia* adults and cocoons	Moderate	Moderate	Poor
61	50.2	(1.49)	(15.2)	(0.45)	(0.80)	Fairly extensive	Extensive	None	Extensive	Extensive	Unacceptable

* Wet weight basis.

** Calculated from Table 2.3.

Figures in brackets are estimated from % moisture content and data in Table 4.2.

Table 4.7 Quality changes during storage of dried salted red snapper

Storage time (days)	Moisture		Salt		a_w**	Moulds	Pinking	Beetles	Rancidity	Putre-faction	Grade
	%*	M_w/M_b	%*	M_s/M_b							
0	51.6	1.56	15.1	0.46	0.80	None	None	None	None apparent	None	Good
10	47.6	1.25	14.0	0.37	0.81	Very slight	Fairly extensive	None	None apparent	None	Good
16	48.6	1.30	13.6	0.36	0.82	Very slight	Extensive	A few adult *Dermestes* and *Necrobia*	None apparent	None	Good
30	48.8	1.33	14.1	0.38	0.82	Moderate	Very extensive	Moderate infestation by *Dermestes* and *Necrobia* adults, some cocoons present	None apparent	Slight	Unacceptable

* Wet weight basis.

** Calculated from Table 2.3.

Three grades of threadfin were studied. The pieces of boneless fish flesh with skin were about 35 cm long and 15 cm wide. They were cut from the boneless portion of fish which had been split in a butterfly cut. The flesh was yellow/orange but had some areas of heavy pinking. The odour was musty and slightly ammoniacal which is characteristic of this product and indicative of some spoilage. The flesh felt moist to the touch. The second sample consisted of pieces of flesh which were 35 cm long and had all three sections of the butterfly cut; the head, tail and gut cavity were absent but the skin was in place. The flesh was yellow and felt drier than the boneless samples; it had the characteristic odour. Although the quality of this product was better than the boneless grade, the latter still commanded a higher price. The third sample was boneless pieces of flesh weighing 115 g each individually packed in polyethylene bags for the consumer. The flesh was yellow and well dried with the characteristic odour. There were no insects present on any of the three samples but there were black speckles on the flesh from blowfly attack.

Table 4.8 indicates the deterioration in all three samples during storage. The boneless samples were wetter after 10 days' storage and the odour was slightly putrid as well as strongly characteristic of the product. The pinking became fairly extensive and, after one month, there were mould colonies present. Beetles also appeared at the same time as did a fairly heavy infestation by blowfly maggots and mites. After two months, the samples had been extensively attack by moulds and had a putrid odour which caused them to be graded as unacceptable.

Mould growth occurred much earlier on the samples with bones: after only 10 days' storage. Slight pinking occurred at the same time. The samples were graded as unacceptable after one month because of extensive mould attack and pinking. Beetles had attacked the fish at the same time and the odour had also become smokey and sour.

The shelf life of the packed threadfin was considerably longer. There was no change in quality until nearly four months of storage when one of the five packs which were examined had extensive mould growth;

Table 4.8 Quality changes during storage of dried salted threadfin

Sample	Storage time (days)	Moisture % *	Moisture M_w/M_b	Salt % *	Salt M_s/M_b	a_w **	Moulds	Pinking	Beetles	Rancidity	Putrefaction	Grade
Threadfin, boneless	0	37.5	0.74	10.7	0.21	0.81	None	Moderate	None	None apparent	Slight	Good
	10	42.5	0.94	11.6	0.26	0.82	None	Fairly extensive	None	None apparent	Slight	Average
	16	48.1	1.22	12.0	0.31	0.83	None	Fairly extensive	None	None apparent	Slight	Average
	30	45.0	1.02	10.6	0.24	0.85	Moderate	Fairly extensive	A few larvae and cocoons	None apparent	Slight	Poor
	61	46.6	(1.07)	(9.1)	(0.21)	(0.88)	Extensive	Fairly extensive	Slight infestation	Slight	Extensive	Unacceptable
Threadfin, with bones	0	37.6	0.80	15.1	0.32	0.75	None	None	None	None apparent	Slight	Good
	10	45.4	1.08	12.3	0.29	0.82	Very slight	Very slight	None	None apparent	Slight	Good
	16	44.0	1.00	11.6	0.26	0.83	Slight	None	None	None apparent	Slight	Average
	30	44.4	1.05	12.9	0.31	0.82	Fairly extensive	Moderate	A few adult *Necrobia*	None apparent	Moderate	Unacceptable
Threadfin, 115g packs	0	40.1	0.91	15.0	0.34	0.75	None	None	None	None apparent	Slight	Good
	10	43.6	1.12	16.5	0.42	0.84	None	None	None	None apparent	Slight	Good
	16	38.1	0.76	11.0	0.22	0.81	None	Slight	None	None apparent	Slight	Good
	30	39.9	0.85	12.2	0.26	0.79	None	None	None	None apparent	Slight	Good
	61	-	-	-	-	-	None	None	None	None apparent	Slight	Good
	87	-	-	-	-	-	None	None	None	None apparent	Slight	Good
	115	-	-	-	-	-	Slight	None	None	Slight	Slight	Good
	143	44.3	(1.08)	(13.9)	(0.34)	(0.77)	None	None	None	Slight	Extensive	Unacceptable

* Wet weight basis. ** Calculated from Table 2.3. Figures in brackets are estimated from the % moisture content and the data in Table 4.2.

this was, in fact, the only incidence of mould attack amongst the packed samples. The other four samples also showed some deterioration in quality. After five months' storage, all the samples became unacceptable due to a strong malodour.

4.1.10 Sardine: These fish are usually caught with anchovy and are processed in the same way (see 4.1.6) except that they are only dried for about 4 hours. The sardines used in this trial were only of average quality. They were whole, ungutted fish with the tails removed. The body measured 8 cm long (without the tail). The flesh was fairly moist although the fish were very brittle and fragmented. The odour was oily, sweet and fruity.

The quality changes during storage are given in Table 4.9. After 10 days' storage, the sardines had suffered from mould attack and a very heavy mite infestation. The odour became more neutral and slightly musty and oily. After 16 days, they were judged as unacceptable because the appearance would give the impression to consumers that they had been stored for a long time.

4.1.11 Mackerel: Whole mackerel are pickle salted in a similar manner to the queenfish (see Section 4.1.7) but less salt is used (100 parts fish: 20 parts salt) since they are smaller. They are salted in the barrels for two days but are only dried for one day in the sun. Usually the gills are removed but the fish are not gutted.

The whole fish used for this trial were about 16 cm long with a fairly moist texture. The odour was oily and slightly putrid. A dead blowfly maggot was found on one of the fish.

After 10 days' storage, the odour became slightly rancid and, by 16 days, some evidence of beetle attack was found (see Table 4.10). The mackerel were graded as unacceptable after one month because the odour was oily, slightly rancid, sour and putrid; moulds were present and some pinking had occurred.

4.1.12 Jewfish: Both whole and split jewfish were used for this study; they are pickle salted in the same way as mackerel (Section 4.1.11) but the gills are left intact.

Table 4.9 Quality changes during storage of dried boiled sardine

Storage time (days)	Moisture		Salt		a_w**	Moulds	Pinking	Beetles	Rancidity	Putre-faction	Grade
	%*	M_w/M_b	%*	M_s/M_b							
0	22.5	0.34	7.5	0.11	0.76	None	None	None	None apparent	None	Average
10	29.9	0.51	8.2	0.14	0.82	Slight	None	None	None apparent	None	Average
16	26.0	0.42	9.1	0.15	0.75	Moderate	None	None	None apparent	None	Unaccept-able

* Wet weight basis.

** Calculated from Table 2.3.

Table 4.10 Quality changes during storage of dried salted mackerel

Storage time (weeks)	Moisture		Salt		a_w**	Moulds	Pinking	Beetles	Rancidity	Putre-faction	Grade
	%*	M_w/M_b	%*	M_s/M_b							
0	48.6	1.68	16.1	0.56	0.75	None	None	None	None apparent	Slight	Good
10	49.1	1.71	15.8	0.55	0.77	None	None	None	Slight	Slight	Good
16	51.8	1.88	14.6	0.53	0.79	None	None	Some orange/ brown cocoons	Slight	Slight	Average
30	48.3	1.59	14.9	0.49	0.78	Moderate	Moderate	Some cocoons present	Slight	Moderate	Unacceptable

* Wet weight basis.

** Calculated from Table 2.3.

The whole fish were 17 cm long and had suffered some physical damage. The flesh was quite moist and an indention was left when pressed with a finger. There were small salt crystals on the skin in places and the fish had a sweet fruity, odour. The split fish were the same length and had been cut along the dorsal side; although they were meant to be gutted, most or, in some cases, almost all of the gut material was intact. The texture was drier and the flesh springy when pressed. The flesh was yellow with orange around the gills and backbone; there were black speckles resulting from blowfly attack. The fish had a strong astringent, ammoniacal odour.

Table 4.11 gives details of deterioration during storage. Although the initial quality of the whole jewfish was better than the split fish, the former became unacceptable much earlier (16 days) than the latter (30 days). After 10 days' storage, the whole fish had a putrid, faecal odour and had suffered heavy pinking. Both of these conditions worsened during the next few days and caused the fish to be rejected. With the split jewfish, the odour also became putrid and faecal but there was no evidence of pinking until 16 days' storage. After one month, these fish had moulds growing on the surface which, together with extensive pinking, caused them to be graded as unacceptable. Both whole and split jewfish had blowfly maggots attacking the flesh after 10 days and the split fish had a few beetle cocoons present by the time that they were rejected.

4.1.13 Pomfret: The exact processing method for these samples is unknown but it is thought that they were probably pickle salted and sun dried in the same manner as the queenfish (Section 4.1.7) or mackerel (4.1.11). The pomfret used for this study were not of very good quality. They were 17 cm long and had been split dorsally followed by gutting although there was some gut material remaining. The gills were intact. There were sand and dirt adhering to the skin. The odour was slightly putrid and ammoniacal. The flesh was a dull yellow/grey colour and had a mushy, moist texture showing evidence of spoilage. There were grains of salt causing a white discoloration on the surface of the fish.

Table 4.12 indicates the changes which occurred during storage. Within 6 days' storage, the flesh had softened further and blowfly maggots and eggs were present on half of the samples. There was evidence of

Table 4.11 Quality changes during storage of dried salted jewfish

Sample	Storage time (days)	Moisture		Salt		a_w**	Moulds	Pinking	Beetles	Rancidity	Putre-faction	Grade
		%*	M_w/M_b	%*	M_s/M_b							
Jewfish, whole	0	42.5	1.23	19.5	0.57	0.75	None	None	None	None apparent	None	Good
	10	45.1	1.32	17.2	0.50	0.76	None	Fairly extensive	None	None apparent	Moderate	Poor
	16	48.4	1.58	17.8	0.58	0.76	None	Very extensive	None	None apparent	Extensive	Unaccept-able
Jewfish, split	0	43.7	1.12	16.7	0.43	0.76	None	None	None	None apparent	Moderate	Average
	10	46.7	1.29	16.6	0.46	0.78	None	None	None	None apparent	Moderate	Average
	16	47.0	1.26	15.2	0.41	0.77	None	Slight	None	None apparent	Moderate	Average
	30	48.7	1.40	15.9	0.46	0.79	Moderate	Extensive	Slight - some cocoons	None apparent	Moderate	Unaccept-able

* Wet weight basis.

** Calculated from Table 2.3.

Table 4.12 Quality changes during storage of dried salted pomfret

Storage time (weeks)	Moisture		Salt		a_w**	Moulds	Pinking	Beetles	Rancidity	Putre-faction	Grade
	%*	M_w/M_b	%*	M_s/M_b							
0	55.6	2.39	20.0	0.86	0.77	None	None	None	None apparent	Slight	Average
6	57.8	2.64	19.2	0.88	0.77	None	None	None	None apparent	Moderate	Poor
12	54.7	2.05	17.5	0.66	0.78	None	Very slight	Slight - some cocoons	Slight	Moderate	Poor
26	56.2	2.34	18.7	0.78	0.77	Slight	Very slight	Slight - some cocoons and adult *Necrobia*	Slight	Moderate	Unacceptable

* Wet weight basis.

** Calculated from Table 2.3.

beetle infestation after 12 days by which time the blowfly maggot infestation was extensive and there was some pinking present; the odour was also slightly rancid. The pomfret were rejected after nearly four weeks when the odour was musty, putrid and rancid and they smelt slightly of urea. There were adult beetles present, extensive maggot infestation, some pinking and white mould colonies which all lead to the rejection on the grounds of appearance.

4.1.14 Catfish: On the East Coast of Malaysia these fish are usually split, gutted and the snout is cut off. They are then placed in a concrete vat with pickle from previous salting batches for one day. This is followed by sun drying.

The catfish used for this study had been split dorsally and gutted, with some gut material left behind which contained worms. The fish were 18 cm long after the snout had been removed. They smelt slightly of ammonia. The flesh was dull yellow/grey, with some white discoloration caused by salt, and was slightly moist. There were some blowfly maggots and eggs present.

The changes in quality during storage are shown in Table 4.13. After 6 days, the odour became slightly oily and rancid. By 12 days, there were a few white moulds growing on the skin, the blowfly maggot infestation had increased and the odour was slightly oily, rancid, sweet and fruity. There was some beetle infestation after nearly one month and some slight pinking; the mould growth had become fairly extensive and the catfish smelt slightly sweet and of urea. After two months, the fish were considered to be unacceptable since they had a putrid odour, were very moist with fairly extensive mould growth and some pinking.

4.2 Determination of sorption isotherms

4.2.1 Proximate analysis: The results of the proximate analysis of the freeze dried octopus, squid, shrimp and anchovy are given in Table 4.14.

Table 4.13 Quality changes during storage of dried salted catfish

Storage time (weeks)	Moisture		Salt		a_w**	Moulds	Pinking	Beetles	Rancidity	Putre-faction	Grade
	%*	M_w/M_b	%*	M_s/M_b							
0	47.5	1.34	12.7	0.36	0.81	None	None	None	None apparent	None	Good
6	53.2	2.00	16.4	0.62	0.79	None	None	None	Slight	Very slight	Good
12	49.9	1.55	13.8	0.43	0.81	Very slight	None	None	Slight	Slight	Average
26	50.7	1.51	11.7	0.35	0.85	Fairly extensive	Slight	Slight - a few adult and larvae *Dermestes* and *Necrobia*	Slight	Slight	Poor
57	52.4	(1.63)	(11.5)	(0.36)	(0.86)	Fairly extensive	Moderate	Slight	Extensive	Extensive	Unaccept-able

* Wet weight basis.

** Calculated from Table 2.3.

Figures in brackets are estimated from the % moisture content and the data in Table 4.2.

Table 4.14 Proximate analysis (% wet weight basis) of freeze dried octopus, squid, shrimp and anchovy

Species	% Moisture	% Salt	% Fat	% Protein	% Ash
Octopus	4.47	4.26	2.20	83.17	6.85
Squid	4.74	4.45	5.39	78.21	7.85
Shrimp	2.71	17.63	2.00	67.72	28.40
Anchovy	2.75	14.22	3.15	71.22	22.30

4.2.2 Isohalic sorption isotherms: Table 4.15 gives the results of the measured moisture (M_w) and salt (M_s) contents of the equilibrated samples at various a_w. The fat (M_f) content at equilibrium, calculated from the results of the proximate analysis (Table 4.14), and the salt-free, fat-free dry mass (M_b) are also presented. The data were used to calculate the moisture contents on a dry mass basis (M_w/M_b) for each sample. The isohalic sorption isotherms for each species were then constructed: Fig. 4.1 presents those for octopus and squid while Fig. 4.2 shows those for shrimp and anchovy.

4.2.3 Sorption isotherms: To compare the isotherms for the different species directly, it is necessary to remove the effect of salt in the sample by calculating the a_{wo} of the samples (see Table 4.16). These data were used to construct the sorption isotherms for octopus, squid, shrimp and anchovy given in Figs. 4.3 - 4.6 respectively together with the sorption isotherm for unsalted cod.

4.3 Redrying and storage of commercially produced samples

4.3.1 Redrying: The moisture and salt contents and a_w values of the samples before and after redrying are given in Table 4.17 together with the weight loss during redrying.

4.3.2 Queenfish: The initial quality of the samples was not as good as those used earlier (see Section 4.1.7). The flesh was darker and there was slight pinking along the gut cavity. After redrying, the queenfish were even darker in colour and the flesh was considerably drier. Table 4.18 indicates the quality changes during storage of

Table 4.15 Sorption data for octopus, squid, shrimp and anchovy

a_w	Octopus				Squid				Shrimp				Anchovy			
	M_w	M_s	M_f	M_b	M_w	M_s	M_f	M_b	M_w	M_s	M_f	M_b	M_w	M_s	M_f	M_b
0.07	7.34	4.19	2.13	86.34	7.08	4.48	5.26	83.18	4.12	16.16	1.98	77.74	3.94	13.68	3.11	79.27
0.22	10.02	3.87	2.07	84.04	8.64	3.69	5.17	82.50	6.59	15.56	1.92	75.93	6.55	13.11	3.03	77.31
0.33	10.36	4.07	2.06	83.51	11.00	3.36	5.04	80.60	7.60	17.48	1.90	73.02	6.89	12.99	3.02	77.10
0.44	12.41	3.43	2.01	82.15	12.99	3.64	4.92	78.45	9.45	17.26	1.87	71.42	8.39	12.35	2.97	76.29
0.54	15.50	3.36	1.94	79.20	16.60	3.12	4.72	75.56	12.19	16.46	1.81	69.54	10.06	12.93	2.91	74.10
0.57	16.80	4.04	1.91	77.25	18.21	3.40	4.63	73.76	14.44	13.67	1.76	70.13	11.83	11.34	2.86	73.97
0.62	17.54	3.81	1.90	76.75	20.61	3.66	4.49	71.24	17.38	14.70	1.70	66.22	13.28	12.77	2.81	71.14
0.65	19.17	3.28	1.86	75.69	20.91	4.33	4.48	70.28	18.40	12.81	1.68	67.11	14.05	11.07	2.78	72.10
0.68	20.26	3.67	1.83	74.24	22.79	3.27	4.37	69.57	22.49	14.10	1.60	61.81	17.05	10.46	2.69	69.80
0.71	21.45	3.82	1.81	72.92	25.30	3.10	4.23	67.37	30.22	13.73	1.44	54.61	22.61	10.80	2.51	64.08
0.73/4	25.01	2.80	1.72	70.47	26.21	2.71	4.18	66.90	33.86	9.73	1.36	55.05	23.53	8.90	2.48	65.09
0.75	25.66	3.22	1.71	69.41	27.16	2.93	4.12	65.79	36.50	10.71	1.31	51.48	29.50	9.65	2.28	58.57
0.80	29.65	3.22	1.62	65.51	31.01	3.45	3.90	61.64	42.50	11.00	1.18	45.32	34.48	9.51	2.12	53.89
0.85	30.12	3.38	1.61	64.89	33.92	2.82	3.74	59.52	45.61	11.15	1.12	42.12	52.52	8.34	1.54	37.60
0.90	38.61	2.92	1.41	57.06	40.83	2.60	3.35	53.22	51.62	8.31	1.00	39.07	46.61	7.65	1.73	44.01

Figure 4.1

Isohalic sorption isotherms for octopus and squid

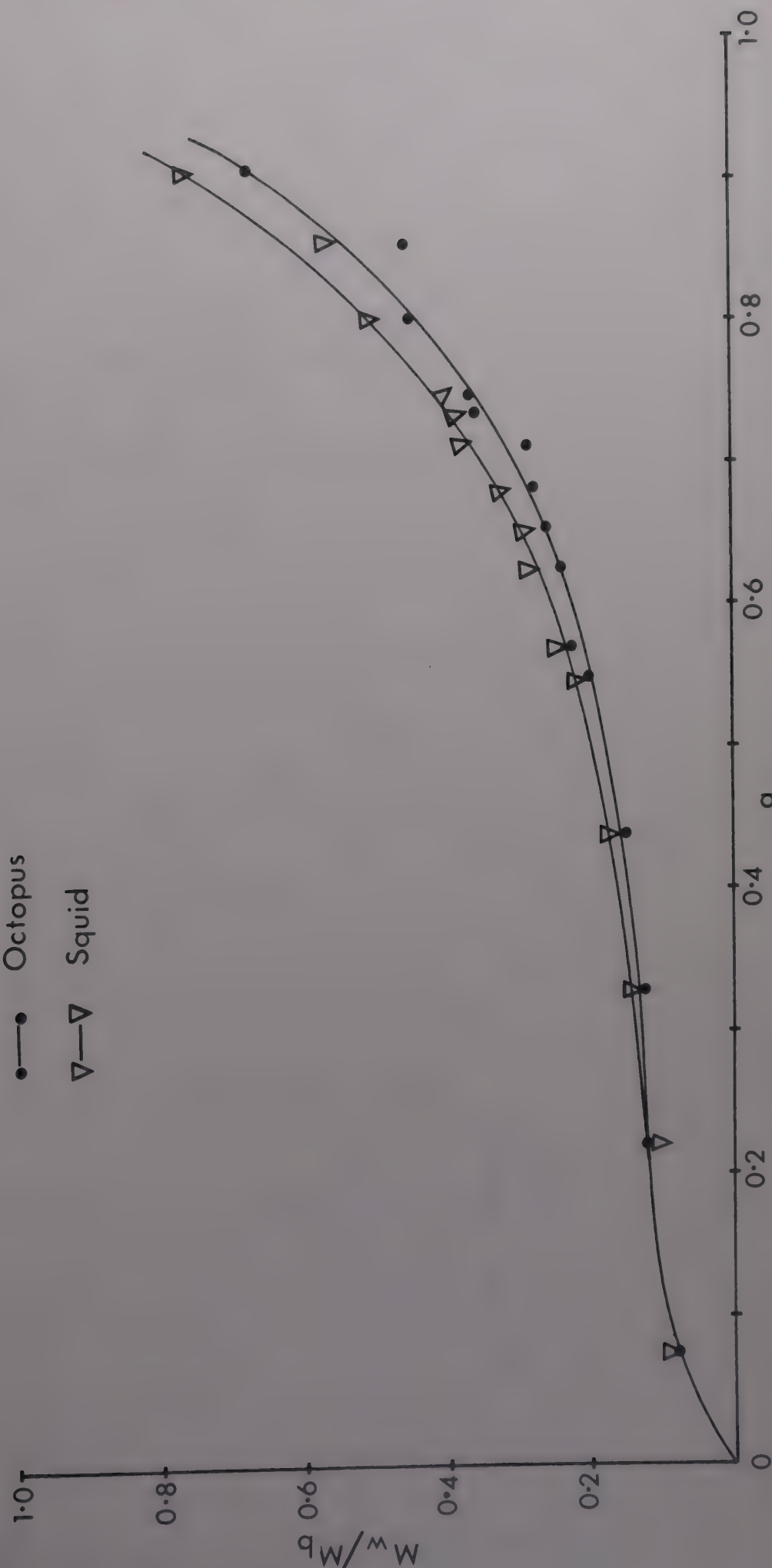


Figure 4.2

Isohalic sorption isotherms for shrimp and anchovy

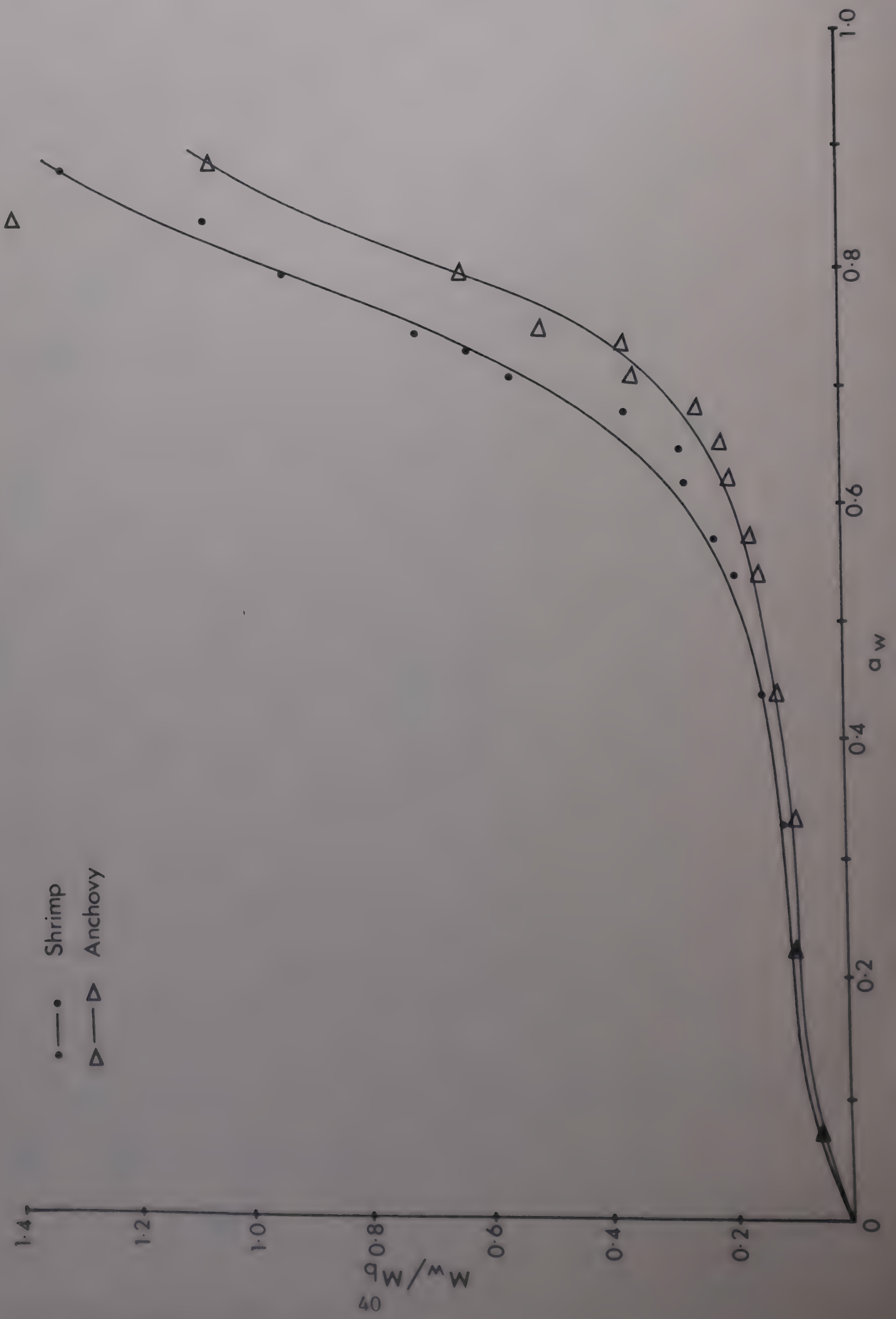


Table 4.16 Calculation of a_{wo} for octopus, squid, shrimp and anchovy

a_w		0.07	0.22	0.33	0.44	0.54	0.57	0.62	0.65	0.68	0.71	0.73/4	0.75	0.80	0.85	0.90
Octopus	M_w/M_b	0.085	0.119	0.124	0.151	0.196	0.218	0.229	0.253	0.273	0.294	0.355	0.370	0.453	0.464	0.677
	a_{wn}	0.75	0.75	0.75	0.84	0.86	0.85	0.86	0.90	0.89	0.89	0.93	0.92	0.94	0.93	0.95
	a_{wo}	0.09	0.29	0.44	0.52	0.63	0.67	0.72	0.72	0.76	0.80	0.80	0.82	0.85	0.91	0.95
Squid	M_w/M_b	0.085	0.105	0.137	0.166	0.220	0.250	0.289	0.298	0.328	0.376	0.392	0.413	0.503	0.570	0.767
	a_{wn}	0.75	0.75	0.80	0.81	0.87	0.87	0.89	0.87	0.91	0.93	0.94	0.93	0.93	0.95	0.96
	a_{wo}	0.09	0.29	0.41	0.54	0.62	0.66	0.70	0.75	0.75	0.76	0.78	0.81	0.86	0.90	0.94
Shrimp	M_w/M_b	0.053	0.087	0.104	0.132	0.175	0.206	0.263	0.274	0.364	0.553	0.615	0.709	0.938	1.083	1.321
	a_{wn}	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.81	0.81	0.83	0.84	0.90
	a_{wo}	0.09	0.25	0.44	0.59	0.73	0.76	0.83	0.87	0.91	0.95	0.91	0.93	0.96	1.01	1.00
Anchovy	M_w/M_b	0.050	0.080	0.089	0.110	0.136	0.160	0.187	0.195	0.244	0.353	0.362	0.504	0.640	1.400	1.059
	a_{wn}	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.78	0.82	0.90	0.90
	a_{wo}	0.09	0.25	0.44	0.59	0.73	9.76	0.83	0.87	0.91	0.95	0.98	0.96	0.98	0.94	1.00

Figure 4.3

Sorption isotherm for octopus

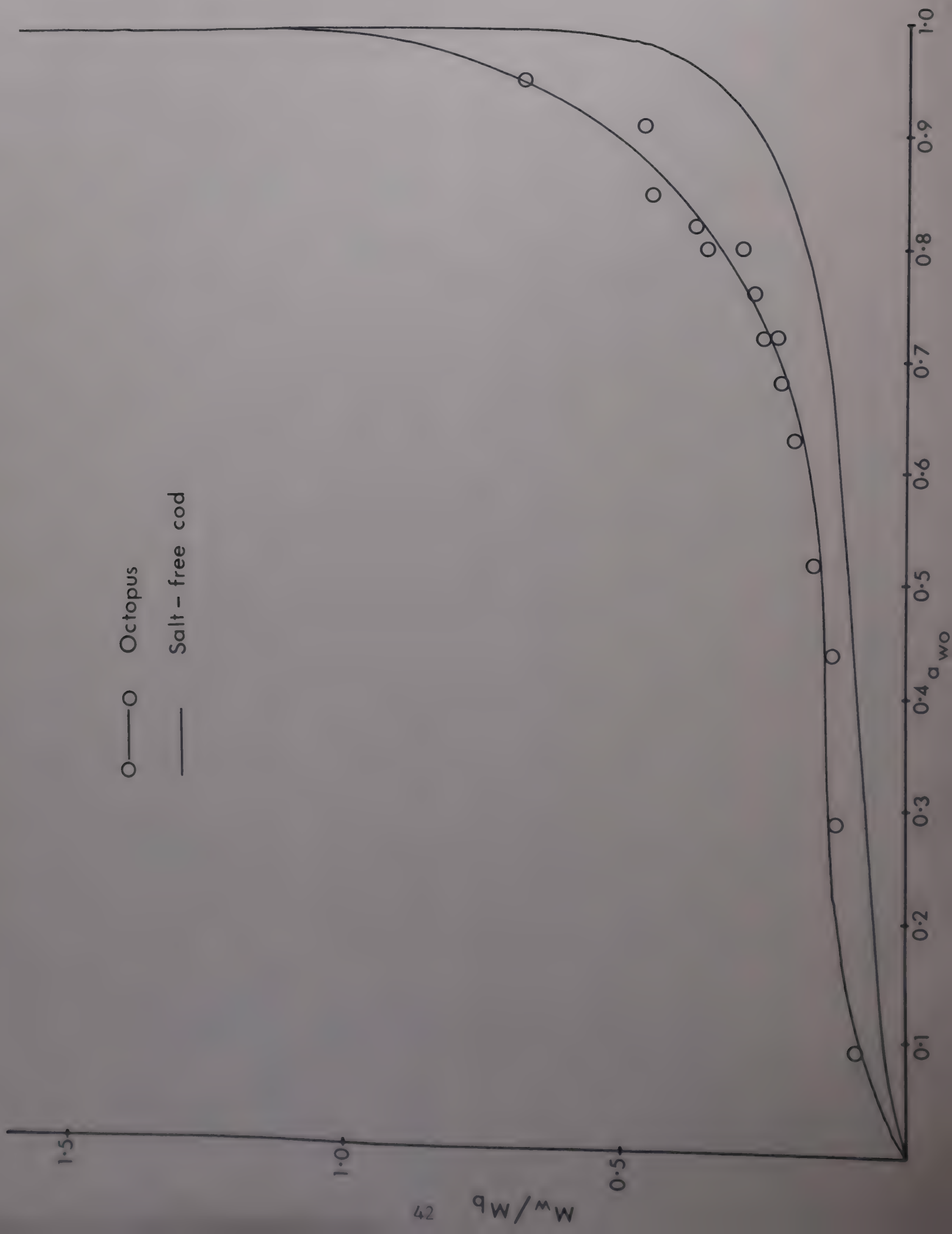


Figure 4.4

Sorption isotherm for squid

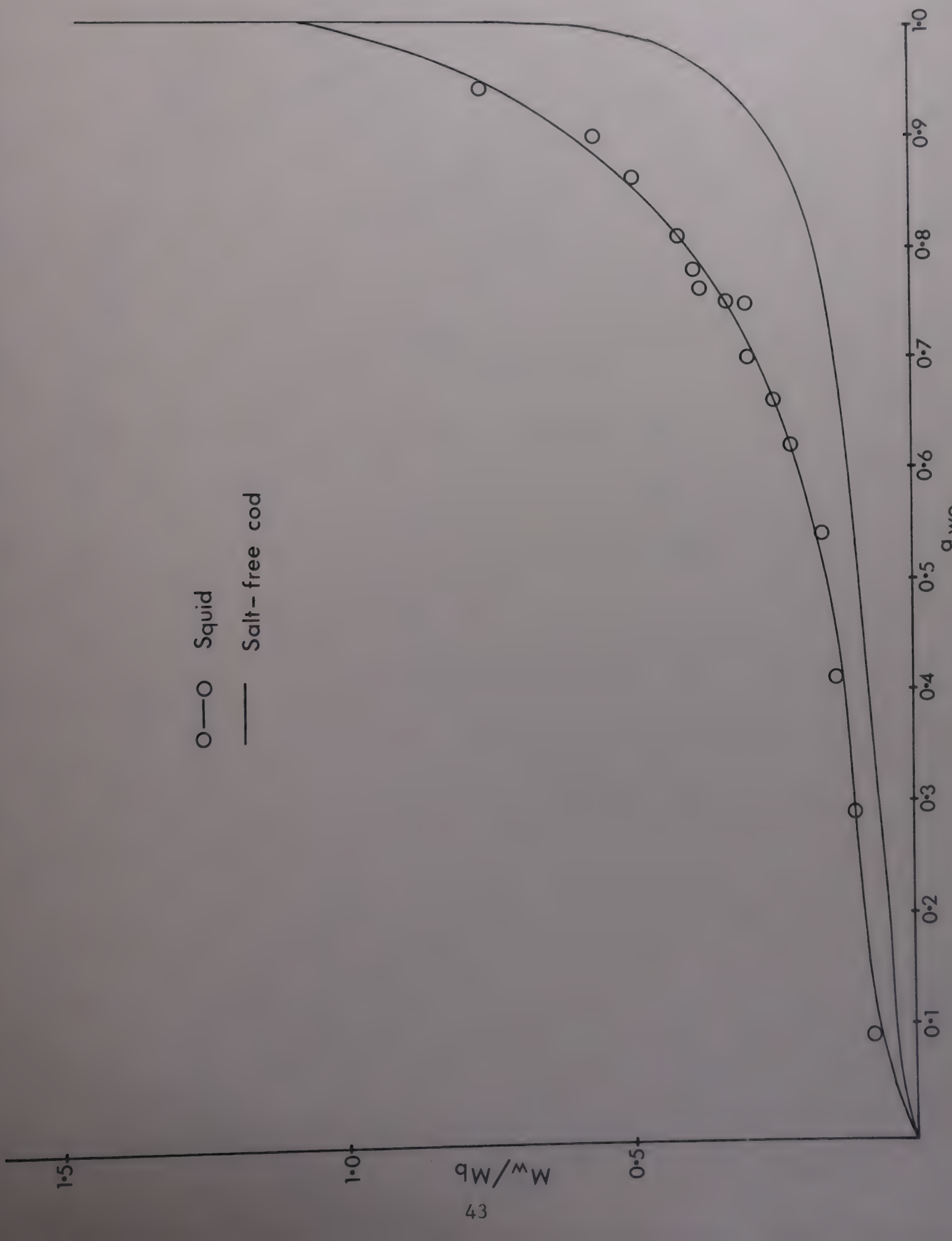


Figure 4.5

Sorption isotherm for shrimp

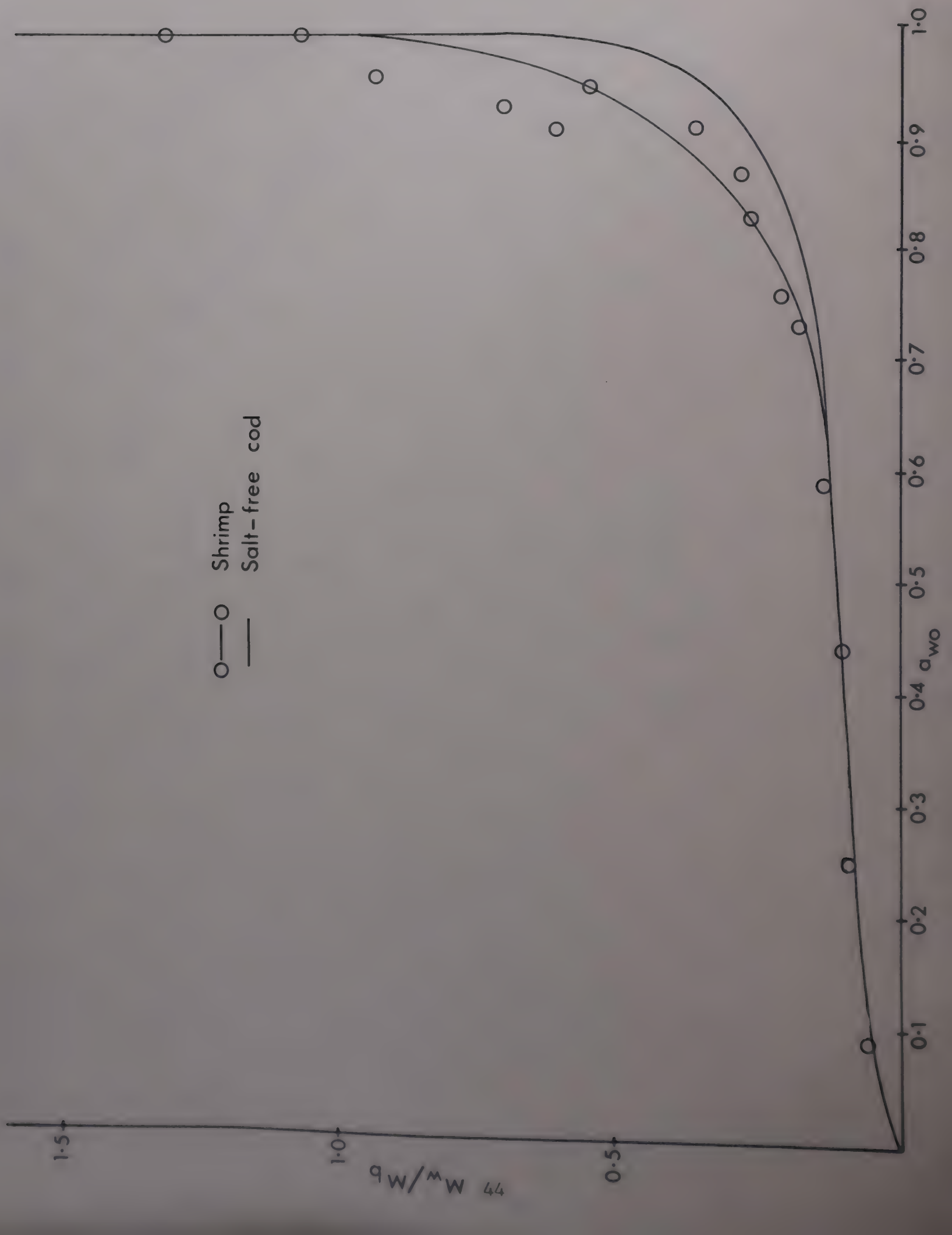


Figure 4.6

Sorption isotherm for anchovy

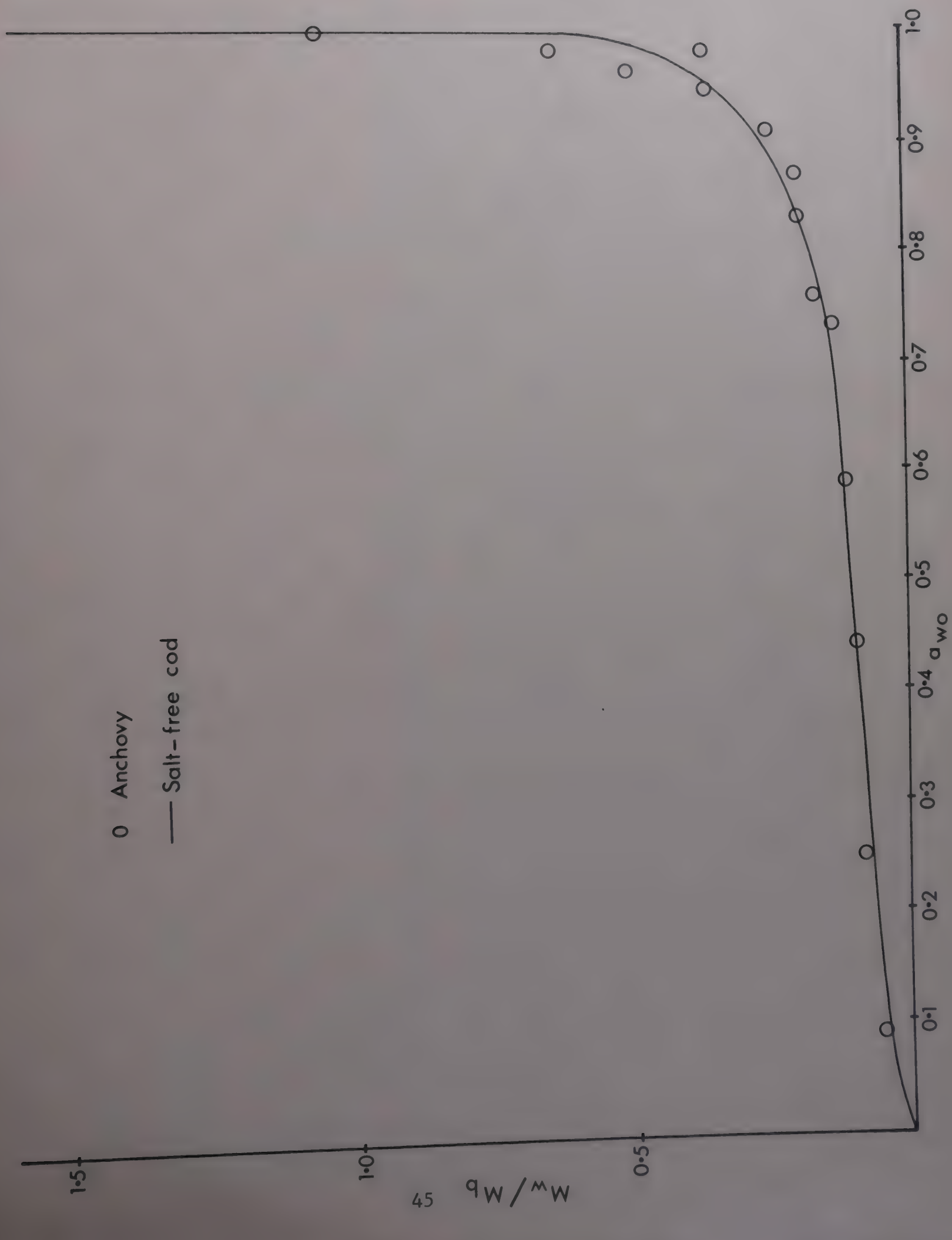


Table 4.17 Redrying data*

Species	Before redrying					% Weight loss during redrying	After redrying				
	% Moisture	M_w/M_b	% Salt	M_s/M_b	a_w		% Moisture	M_w/M_b	% Salt	M_s/M_b	a_w
Queenfish	53.7	1.74	14.6	0.47	0.82	17	42.9	1.06	15.6	0.39	0.75
Red snapper	51.3	1.51	14.5	0.43	0.81	22	28.6	0.55	19.1	0.37	0.75
Threadfin	39.8	0.85	12.7	0.27	0.78	12	33.6	0.63	12.3	0.23	0.75
Jewfish	48.7	1.46	15.3	0.47	0.79	24	41.1	1.20	21.0	0.61	0.75
Pomfret	48.0	1.30	13.9	0.38	0.82	14	40.9	1.10	20.5	0.55	0.75

* % Moisture and salt contents are on a wet weight basis and a_w values calculated from Table 2.3 and data in Table 4.2.

Table 4.18 Quality changes during storage of commercial and redried queenfish

Sample	Storage time (days)	Moulds	Pinking	Beetles	Rancidity	Putrefaction	Grade
Commercial samples	0	None	Very slight	None	None apparent	None	Good
	8	None	Very slight	None	None apparent	None	Good
	16	Moderate	Moderate	Slight - a few *Dermestes* adults and larvae	Slight	Slight	Average
	29	Extensive	Extensive	Slight - *Dermestes* larvae	Extensive	Slight	Unacceptable
Redried samples	0	None	Very slight	None	None apparent	None	Good
	8	None	Very slight	Slight - a few adult *Dermestes* and *Necrobia*	None apparent	None	Average
	14	None	Slight	Slight - a few adult *Dermestes*	Slight	Slight	Average
	28	Slight	Slight	None	Slight	Slight	Poor
	56	Moderate	Slight	None	Slight	Slight	Unacceptable

the original commercial and redried queenfish. The commercial samples developed mould growth after 16 days compared with 28 days in the redried queenfish; pinking also worsened at the same time in the former. The odour of these samples became overpoweringly sweet within a few days' storage which did not happen with the redried fish: their odour became musty after a fortnight's storage. The commercial samples became unacceptable by four weeks while redrying extended the shelf life of the queenfish to nearly two months.

4.3.3 Red snapper: The samples, when purchased, were similar to the earlier batch of fish (see Section 4.1.8): the quality was very good, the odour was fresh and salty while the flesh was fairly moist and springy to the touch. The flesh became harder and well dried and the odour remained fresh following redrying. The changes in quality of the samples are given in Table 4.19. The quality of the commercial samples deteriorated very quickly compared with the redried red snapper and the storage lives of the two sets of fish were similar to those of the queenfish. Although mould growth developed on both at the same time (about two weeks), pinking developed much earlier in the commercial samples and both conditions worsened considerably more in these fish.

4.3.4 Threadfin: Several 115g packs of threadfin were used for this part of the study. The pieces of fish were removed from the packs for storage or redrying and storage. The quality was similar to the earlier packaged threadfin (see Section 4.1.9). The flesh was moist to touch but was not dented by pressure from a finger. The samples were dark yellow/orange and had the strong odour characteristic of the product. After redrying, the flesh was firm but not too hard. The deterioration during storage of the products is detailed in Table 4.20. The redried samples appeared to decrease in quality earlier than the commercial samples: the former were wet on the surface due to sweating which made them less attractive to the consumer. Mould appeared on the commercial samples after one month. The trial had to be terminated after this since all of the samples were found to have been stolen from the store at the next sampling.

4.3.5 Jewfish: Whole fish, which were only 12 cm long and, therefore, smaller than those used earlier (see Section 4.1.12), were purchased for this study. The flesh was moist and dented when subjected to finger pressure. The odour was salty, musty and slightly putrid. The fish

Table 4.19 Quality changes during storage of commercial and redried red snapper

Sample	Storage time (days)	Moulds	Pinking	Beetles	Rancidity	Putrefaction	Grade
Commercial samples	0	None	None	None	None apparent	None	Good
	8	None	Very slight	Slight - a few *Necrobia* adults	None apparent	None	Good
	16	Slight	Moderate	None	None apparent	None	Average
	29	Extensive	Extensive	Slight - a few adults and larvae	None apparent	None	Unacceptable
Redried samples	0	None	None	None	None	None	Good
	8	None	None	Slight - a few adult *Necrobia* and *Dermestes*	None	None	Good
	14	Slight	None	Slight - (*Dermestes* adults)	None	None	Good
	28	Slight	Slight	None	None	None	Good
	56	Fairly extensive	Slight	None	None	None	Unacceptable

Table 4.20 Quality changes during storage of commercial and redried threadfin

Sample	Storage time (days)	Moulds	Pinking	Beetles	Rancidity	Putrefaction	Grade
Commercial samples	0	None	None	None	None	Very slight	Good
	8	None	None	None	None	Very slight	Good
	16	None	None	None	None	Very slight	Good
	29	Slight	None	None	None	Very slight	Average
	57 (missing)						
Redried samples	0	None	None	None	None	Very slight	Good
	8	None	None	None	None	Very slight	Good
	14	None	None	None	None	Very slight	Average
	28	None	None	None	None	Very slight	Average
	57 (missing)						

had been damaged physically and there were blowfly maggots present. After redrying, the fish were hard and well dried while the odour had become more neutral, masking the spoilage which had occurred. The changes in quality during storage are shown in Table 4.21. The redried samples were graded as unacceptable (28 days) before the commercial samples (57 days) although the quality of the latter was poor after one month's storage. Pinking developed after only 16 days in the commercial samples but, at 28 days, the redried samples had extensive pinking which did not occur until much later in the former. Mould growth developed on both samples after one month.

4.3.6 Pomfret: The fish used for this study were of better quality than the earlier samples (see Section 4.1.13). They had been split and gutted but the gills were intact. The flesh was yellow/orange in colour with a glaze; it was moist but did not dent under finger pressure. The odour was slightly faecal and of ammonia. After redrying, the flesh was still slightly moist and soft but further moisture loss resulted in an unattractive product. The quality changes during storage are given in Table 4.22. After one week's storage, the commercial samples had an oily aroma and were moist; one week later, mould growth started to develop and, after one month, pinking also developed. Moulds and pinking developed after one week in the redried samples but affected only a few of the fish. The odour at this time had become oily, smokey and quite pungent. After two weeks' storage, the pinking had worsened slightly. The samples were stolen from the store soon afterwards and the trial had to be terminated.

4.4 Processing and storage of dried salted fish

Initial salting trials with one batch of each fish species were carried out to estimate the brining times and weight losses during drying required to produce samples covering the range of moisture and salt contents considered in Table 2.4. It was found that this was extremely difficult to achieve. The scad had very thick skin which was a barrier to salt penetration during brining and moisture loss during drying even when the skin had been scored. Following the initial work, the intention was to produce bream with approximately the same moisture content (25%) and a range of salt contents (5-20%) and scad with a range of moisture contents (30-50%) and the same salt content (5%). The results of the proximate analysis of the fresh muscle of hairtail scad and threadfin bream are given in Table 4.23 and the moisture and salt contents

Table 4.21 Quality changes during storage of commercial and redried jewfish

Sample	Storage time (days)	Moulds	Pinking	Beetles	Rancidity	Putrefaction	Grade
Commercial samples	0	None	None	None	None	Very slight	Good
	8	None	None	None	None	Very slight	Good
	16	None	Slight	None	None	Slight	Good
	29	Slight	Slight	None	Slight	Slight	Poor
	57	Slight	Extensive	None	Slight	Slight	Unacceptable
Redried samples	0	None	None	None	None	None	Good
	8	None	None	None	None	None	Good
	14	None	None	None	None	None	Good
	28	Slight	Extensive	None	Slight	Slight	Unacceptable

Table 4.22 Quality changes during storage of commercial and redried pomfret

Sample	Storage time (days)	Moulds	Pinking	Beetles	Rancidity	Putrefaction	Grade
Commercial samples	0	None	None	None	Slight	Very slight	Good
	8	None	None	None	Slight	Very slight	Good
	16	Slight	None	None	Slight	Very slight	Good
	29	Slight	Slight	Slight - a few *Dermestes* adults	Slight	Slight	Average
	57 (missing)						
Redried samples	0	None	None	None	Slight	None	Good
	8	Slight	Very slight	None	Slight	None	Average
	14	Slight	Moderate	None	Slight	None	Average
	28 (missing)						

and a_w values of the final dried salted products are presented in Table 4.24.

Table 4.23 Proximate composition (% wet weight basis) of fresh hairtail scad and threadfin bream

Species	Hairtail scad	Threadfin bream
% Moisture	77.5	78.9
% Salt	0.3	0.3
% Fat	1.1	0.9
% Protein	20.6	18.3
% Ash	1.2	0.9

Table 4.24 Moisture and salt contents and a_w values of final dried salted hairtail scad and threadfin bream samples

Species	Sample no.	Moisture		Salt		a_w**
		%*	M_w/M_b	%*	M_s/M_b	
Hairtail scad	S1	40.7	0.78	4.3	0.08	0.94
	S2	47.1	1.02	3.9	0.08	0.96
	S3	43.4	0.85	2.6	0.05	0.97
	S4	30.4	0.50	4.9	0.08	0.90
Threadfin bream	B1	24.2	0.36	5.6	0.08	0.83
	B2	21.9	0.34	9.6	0.15	0.72
	B3	23.5	0.42	16.6	0.29	0.74
	B4	25.6	0.39	5.1	0.08	0.85

* Wet weight basis.

** Calculated using Table 2.3.

The storage trials with these samples commenced towards the end of the visit. Unfortunately, six of the eight samples disappeared from the store within a few days and there was insufficient time to repeat the processing; therefore, the results of most of this research are lost.

4.5 Testing an inexpensive water activity meter

The results of the a_w values (a_w meas.) obtained by using the water activity meter are given in Table 4.25 together with the a_w values calculated (a_w calc.) using either Table 2.3 or the sorption isotherm constructed in Section 4.2. Figure 4.7 is a plot of the measured a_w against the calculated a_w for the data in Table 4.25. A least squares linear regression fit of these data gives the relationship:

$$a_w \text{ (meas.)} = 0.602 + 0.227\ a_w \text{ (calc.)}$$

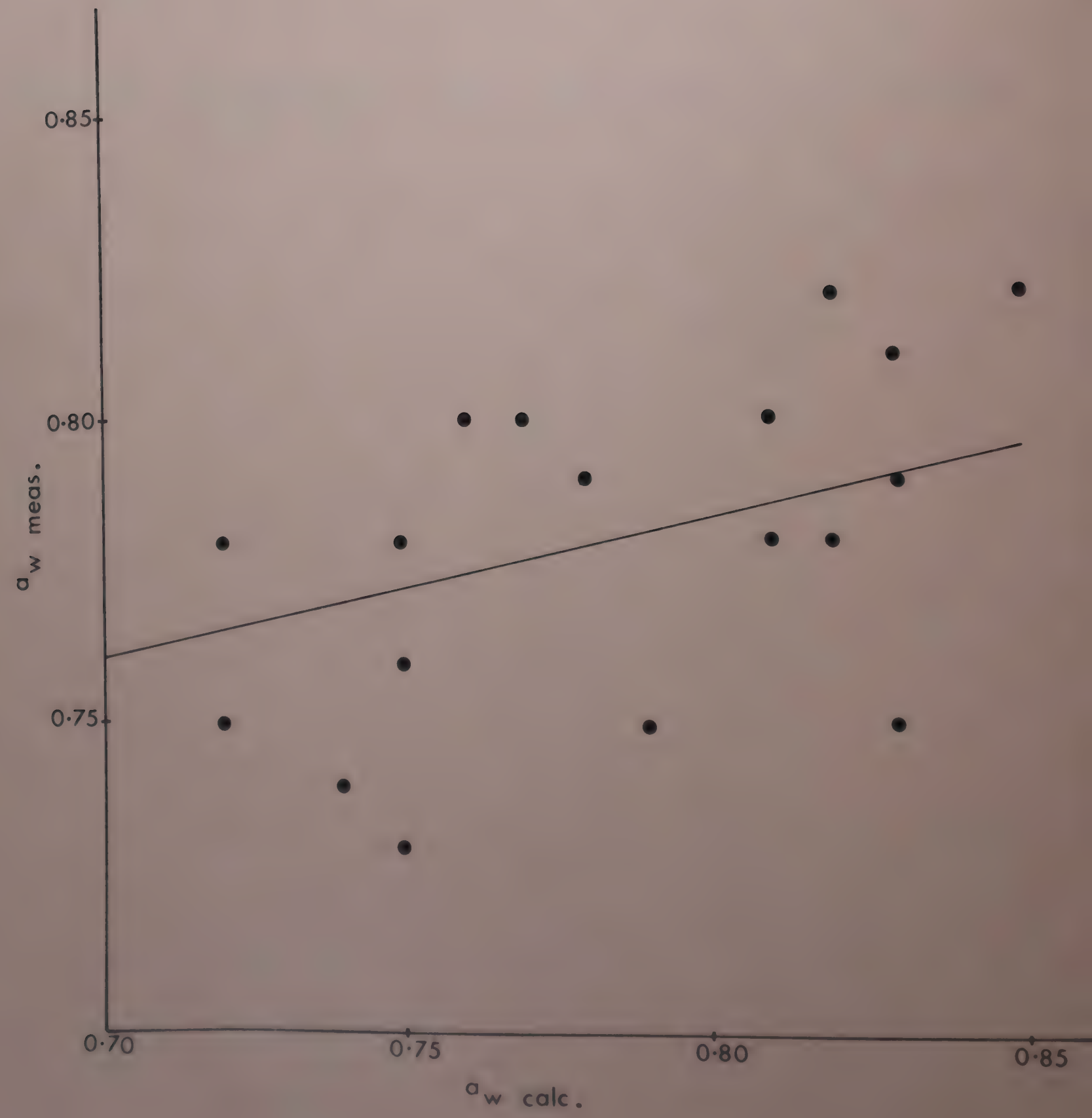
with a correlation coefficient, r = 0.347.

Table 4.25 Calculated and measured a_w values for Malaysian cured fish products

Species	a_w calc.	a_w meas.
Octopus	0.76	0.80
Squid	0.72	0.78
Shrimp	0.81	0.78
Anchovy	0.81	0.78
Anchovy	0.81	0.80
Queenfish	0.83	0.81
Snapper	0.82	0.82
Snapper	0.75	0.76
Threadfin	0.85	0.82
Threadfin	0.82	0.78
Threadfin	0.75	0.73
Threadfin	0.79	0.75
Mackerel	0.78	0.79
Jewfish	0.78	0.79
Jewfish	0.75	0.78
Pomfret	0.77	0.80
Catfish	0.83	0.79
Threadfin bream	0.83	0.75
Threadfin bream	0.72	0.75
Threadfin bream	0.74	0.74

Figure 4.7

Relationship between measured and calculated water activities



5. DISCUSSION

The initial a_w values of the cured fisheries products, calculated using the method of Doe *et al.* (1982 and 1983), were used to predict their mould-free shelf lives during storage according to the work of Poulter *et al.* (1982). Where possible, the moisture and salt contents were used to estimate the minimum good quality storage life of the products from Poulter's (1980) Table. These predictions were compared with the results obtained during the storage trials; a summary of these data is given in Table 5.1.

The initial a_w values for the commercial dried salted fish ranged between 0.75 and 0.82 suggesting mould-free shelf lives between 1 and 5 weeks. These predictions held for most of the samples. There were four exceptions to this:

(a) The threadfin with the bones in and the mackerel were attacked by moulds earlier than expected. However, like most of the samples, the a_w increased during storage to equilibrate with the relative humidity and the predictions held when the a_w for the length of storage was taken into consideration; i.e. most of the samples with an a_w above the curve in Fig. 2.4 after a certain storage time had mould colonies present while those samples with an a_w below the curve showed no mould growth.

(b) Only one of the packaged threadfin samples exhibited mould growth and this was after 4 months. The other samples were unaffected. The packaging obviously offered protection against attack by moulds.

(c) The boneless threadfin samples were attacked by moulds much later than expected, i.e. samples with an a_w above the curve in Fig. 2.4 had no mould colonies present. However, the samples suffered extensive pinking which could have interferred with mould growth.

Apart from the threadfin samples, it was not possible to use the Table prepared by Poulter (1980) to predict the storage life of the dried salted fish since the moisture contents were too high. Generally, Malaysians have a preference for dried salted fish which is still fairly wet and not hard dried (see Latif *et al.*, 1983, who describe the characteristics of good quality dried fish in Malaysia). However, the actual acceptable storage life of the threadfin samples was in good agreement with the predictions except for the packaged samples which remained in good condition for several months longer than expected.

Table 5.1 Summary of storage trial data

Product	Moisture %	Salt %	a_w	Predicted mould-free shelf life	Actual time moulds appeared	Predicted minimum good quality storage life	Actual minimum acceptable quality storage life	Reason for unacceptable grading
Cephalopods:								
Octopus	33.6	6.9	0.80	10d	10d	½ wk	1½ wk	Mould growth
Squid	26.3	2.8	0.73	6d	16d	*	1½ wk	Mould growth
Shrimp:								
High grade	32.4	10.4	0.76	31d	30d	2 wk	1 m	+
Low grade	32.9	13.3	0.73	58d	>30d	2 m	½ m	+
Dried boiled fish:								
Anchovy, high grade	29.5	9.2	0.79	14d	16d	1½ m	½ m	+
Anchovy, low grade	38.9	12.0	0.80	10d	16d	1 wk	½ m	Mould growth
Sardine	22.5	7.5	0.76	31d	10d	2½ m	½ m	Mould growth
Dried salted fish, commercial samples:								
Queenfish	53.5	14.2	0.82	7d	10d	*	½ m	Moulds, pinking, putrefaction
Queenfish	53.7	14.6	0.82	7d	16d	*	½ m	Heavy pinking
Red snapper	51.6	15.1	0.80	10d	10d	*	½ m	Heavy pinking and mould growth
Red snapper	51.3	14.5	0.81	9d	16d	*	½ m	Heavy pinking and mould growth
Threadfin, boneless	37.5	10.7	0.81	8d	30d	1 wk	½ m	Mould growth and putrefaction
Threadfin, with bones	37.6	15.1	0.75	37d	10d	3 wk	½ m	Mould growth and pinking
Threadfin, 115g packs	40.1	15.0	0.75	37d	115d	3 wk	4 m	Putrefaction
Threadfin, 115g pieces, unpacked	39.8	12.7	0.78	19d	29d	3 wk	1 m	+
Mackerel	48.6	16.1	0.75	37d	30d	*	½ m	Putrefaction
Jewfish, whole	42.5	19.5	0.75	37d	-	*	1 wk	Heavy pinking
Jewfish, whole	48.7	15.3	0.79	14d	29d	*	½ m	Pinking, moulds and putrefaction
Jewfish, split	43.7	16.7	0.76	31d	30d	*	½ m	Heavy pinking and moulds
Pomfret	55.6	20.0	0.77	25d	26d	*	1 wk	Putrefaction, pinking and moulds
Pomfret	48.0	13.9	0.82	7d	16d	*	> 1 m	+
Catfish	47.5	12.7	0.81	8d	12d	*	½ m	Putrefaction, pinking and moulds

Table 5.1 contd.

Product	Moisture %	Salt %	a_w	Predicted mould-free shelf life	Actual time moulds appeared	Predicted minimum good quality storage life	Actual minimum acceptable quality storage life	Reason for unacceptable grading
Dried salted fish, redried samples:								
Queenfish	42.9	15.6	0.75	37d	28d	*	½ m	Pinking, moulds and putrefaction
Red snapper	28.9	19.1	0.75	37d	14d	2 m	1 m	Moulds and pinking
Threadfin, 115g pieces, unpacked	33.6	12.3	0.75	37d	28d	2 wk	1 m	+
Jewfish	41.1	21.0	0.75	37d	28d	1½ m	2 wk	Putrefaction, pinking and moulds
Pomfret	40.9	20.5	0.75	37d	8d	1½ m	2 wk	+

* Unable to predict either because the moisture content was too high or the salt content too low.
+ Trial terminated prematurely because the samples were stolen from the store.

After redrying, the commercial dried salted fish samples all had an a_w value of 0.75. This was not intentional, in cases where further drying to an even lower moisture content had been planned (eg. queenfish and pomfret), the fish became very unattractive and would have been unacceptable to Malaysian consumers. Even when drying mechanically, under the prevalent weather conditions, it had been difficult to achieve some of the weight losses. The predictions for mould-free shelf life and good quality storage life were, in all but one case, unreliable for these samples. Mould growth occurred earlier than expected and the fish became unacceptable much sooner than anticipated. Therefore, although redrying will give some extension to the storage life in most cases, it will not be to the same extent as would be expected had the same a_w or moisture content been achieved during the original drying process. Obviously any microbial attack or putrefaction which occur between drying and redrying, or during redrying itself, are not reversible. Even though redrying delays the effects of these spoilage processes, it cannot overcome the damage they have already caused. The exception to these results was the threadfin samples; both the predictions appeared to hold for this product. However, these had originally been packed in polyethylene bags which appeared to halt most mould attack and prolong the storage life as was seen during the first storage trials. Obviously the packaging protected the fish from spoilage and microbial attack between drying and redrying. It is of interest that the predictions for the commercial threadfin samples were all reasonably successful but it was highly probable that the importer in Penang would have redried these fish before selling them (see Section 4.1.9).

The predictions for the octopus and shrimp samples agreed with the results obtained during the storage trials. However, this was not true of all the cooked/boiled samples (shrimp, anchovy and sardine). The predictions were successful for the high grade shrimp but not the low grade. The mould-free shelf life estimates held for both grades of anchovy but the minimum good quality storage life predictions were less reliable. The sardine predictions were completely unsuccessful; however, these fish were not of the highest quality when purchased. The effect of cooking/boiling on the acceptable storage life is not entirely clear and requires further investigation; however, the mould-free shelf life predictions appear to be reliable for cooked/boiled products provided that they are of high quality.

Zain and Yusof (1983) recently conducted a survey of the salt and moisture contents of Malaysian dried fish. Generally, the products used for this study were of higher moisture and lower salt contents (on a wet weight basis)

and, therefore, higher a_w. These differences could be due purely to climatic conditions. It is not known at what time of year Zain and Yusof (1983) carried out their research; it may have been drier weather than the wet, humid conditions encountered during this study which is supported by the difficulty when trying to sun dry the commercial samples.

As can be seen from Table 5.1, the main problems during storage were mould growth and pinking, and also putrefaction but to a much lesser degree. Beetle infestation was not a problem, only a few adults and larvae were found, but blowfly maggots were often found in the wetter samples. Mite infestation was also encountered. This type of pattern is in agreement with the FAO review (1981) of principal loss-causing agents under different tropical climatic conditions.

The a_w values calculated in Table 2.3 are based on the sorption isotherm for freeze dried unsalted cod at 25°C. Curran and Poulter (1983) reported that the isotherm could be applied to tropical species of fish and that it would appear to be unaffected by the processing temperatures during sun and solar drying. However, work on cooked fish by Tarr (1945), Shewan (1953) and Cutting *et al.* (1956) has shown that the temperature of the samples during drying affected the isotherms obtained. Recent data obtained at TDRI (Poulter *et al.*, 1984) have indicated that this is also probably true of (initially) uncooked samples. Traditionally, anchovies are boiled in brine before drying and the effect of this process on the isotherm is unknown. In addition, it is not known whether the isotherm for the vertebrate fish, cod, can be applied to the invertebrate crustaceans and cephalopods. For these reasons, it was necessary to construct isotherms for the anchovy (assuming the effect of boiling sardine would be similar), shrimp, octopus and squid which would then be used to calculate the a_w of the samples.

The isohalic sorption isotherms for octopus, squid, shrimp and anchovy (Figs. 4.1 and 4.2) were all different as would be expected from their different classification and salt contents. A comparison between the water sorption isotherms (i.e. where the influence of salt is removed) shows that the data for anchovy fit the isotherm for cod (Fig. 4.6). This indicates that the boiling step during processing does not affect the isotherm as might be expected. Since the fish are only boiled for one minute, it may be that this process is not severe enough to cause changes in the muscle proteins which would affect the isotherms as was suggested by the solar drying work of Curran and Poulter (1983). From these results, it was concluded that the a_w of dried boiled anchovy and sardine could be calculated using Table 2.3.

The sorption isotherms for shrimp, octopus and squid all differed from each other and from that of cod. The work on fish might have suggested that the isotherms for octopus and squid, being from the same phylum, might be the same or very similar. As a consequence of these results, it was obvious that Table 2.3 could not be used to calculate the a_w of the samples. Therefore, this was determined using the moisture and salt contents together with the relevant sorption isotherm and the method of Doe *et al.* (1982).

The a_w meter was not very reliable during this study when used in the IPM laboratory. The meter was simply left on a bench during calibration and sample testing; no attempt was made to control the temperature which ranged between 29 and 33°C over the course of the work. There is a degree of uneven salt penetration and distribution in cured products which could lead to discrepancies in the measured and calculated a_w values. However, it was considered that this problem was eliminated. Therefore, since Doe *et al.* (1983) found a good correlation ($r = 0.99$, $p < 0.001$) between their method for calculating a_w and the actual a_w of a sample, it can be assumed that the calculated a_w values are representative of the true a_w and it is the a_w meter which is unreliable.

Further work at the TDRI laboratories indicated that the meter was reliable when placed in a temperature-controlled incubator at 20 or 25°C. However, it was noted both in Malaysia and London that the two sensor heads registered slightly different temperatures during testing at a time when they would be expected to be the same. The Malaysian samples were all within a narrow range of a_w values (0.72 - 0.83); the meter may have been found to be more accurate over a wider range.

6. CONCLUSIONS

The work with Malaysian cured fisheries products indicated that the Table produced by Poulter (1980) could be used as a guide to predict the good quality storage life (i.e. when the products would be readily acceptable to consumers) of dried salted fish and cephalopods simply from the moisture and salt contents. It cannot be used for predicting the shelf life of dried cooked/boiled products (but a separate Table could be constructed for use with these) or redried fish. The Table needs to be expanded to include products with higher moisture contents (see Table 6.1). Theoretically, at high moisture (45-55%) and salt (20%) contents, longer shelf lives than those indicated in Table 6.1 would be expected. However, the results of this study suggest that these figures are likely to be more accurate predictions.

The predictions for mould-free shelf life from the a_w value follow a similar pattern to the acceptable storage life results. They are successful for dried salted fish and cephalopods and possibly high quality dried cooked/brined products but are unreliable with redried products.

Packaging in polyethylene bags extended the shelf life of dried salted fish by several months. Although there can be problems when packing cured products in this way, the FAO review (1981) indicated that there should be little trouble with small retail packages which supports the results of this study. In Penang, it is usually dried salted threadfin which is packaged as well as a much wetter product, Spanish mackerel, from Thailand. Interestingly, Malaysian wholesalers maintain cold storage facilities to keep their stock in top quality condition (Hanson and Esser, 1982; Maynard, 1983) which can reduce losses considerably.

Boiling small fish in brine for a short period did not affect the sorption isotherm. Consequently, the sorption isotherm for unsalted freeze dried cod and, therefore, Table 2.3 can be used to calculate the a_w of dried boiled anchovy and sardine. The sorption isotherms for dried cooked shrimp and dried octopus and squid differed from that of cod. Therefore, Table 2.3 could not be used to calculate the a_w of these products; it was necessary to determine these values from the basic method of Doe *et al.* (1982).

The a_w-Value Analyzer model no. 5803 was not very reliable when used in the IPM laboratories on the bench. It was more successful when kept in a

temperature-controlled incubator. The manufacturers claim that the meter was designed for laboratory and field work. On the evidence of this study, it could not be recommended for the latter.

Table 6.1 Guide to the shelf life of cured fisheries products with different moisture and salt contents

% Moisture	% Salt	Minimum acceptable storage life
55	5	Less than ½ week
	10	Less than ½ week
	15	1 week
	20	½ week
50	5	Less than ½ week
	10	Less than ½ week
	15	1½ weeks
	20	1 week
45	5	Less than ½ week
	10	Less than ½ week
	15	2½ weeks
	20	1 week
40	5	½ week
	10	1 week
	15	3 weeks
	20	1½ months
35	5	½ week
	10	2 weeks
	15	2 months
	20	1½ months
30	5	½ week
	10	1½ months
	15	2 months
	20	2 months
25	5	1 week
	10	2½ months
	15	2 months
	20	2 months
20	5	3 weeks
	10	4 months
	15	4 months
	20	3½ months
15	5	More than 1 year
	10	More than 1 year
	15	More than 1 year
	20	More than 1 year

7. REFERENCES

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